CHAPTER 1

Introduction

The term "environment", in general, means the surroundings of an object. It is defined as the sum total of all living (biotic) and nonliving (abiotic) components. An environment encompasses all conditions necessary for the existence and growth of all living organisms, including human beings. An environment is never static; it undergoes a process of continuous change, which affects all living creatures on earth. Many species that cannot adapt to the changing environmental conditions perish. The complete extinction of dinosaurs from the planet is an example, which is attributed to adverse environmental conditions. One of the many theories of this extinction is the appearance of many tiny primitive mammals that ate dinosaur eggs.

The environment provides different resources necessary for the sustenance and growth of all life forms. Three primary natural resources available are

Deforestation and degradation of land

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air, water, and land. In addition, sun is a major source of energy for all. Other nutrients and minerals found in plants and soil are also freely available.

Human activities are responsible for the degradation of environment. Some of these activities are listed below.

- Deforestation of land by cutting trees for wood and use of forest land for cultivation are required for the ever-increasing population. Deforestation has been occurring for thousands of years.
- Since time immemorial, gentle animals are killed for food and fierce animals for safety reasons. This has led to the extinction of a large number of animal species.
- Industrialization has a tremendous impact on environment. Various industries are responsible for atmospheric pollution because they discharge a large number of harmful and poisonous gases. Industrial effluents are responsible for the pollution of soil and various waterbodies, including underground water. Various pollutants are also responsible for adverse effects on human health. In fact, the discharge of effluents in waterbodies is responsible for various diseases like Minimata disease, Itai-Itai disease, and Methemoglobinemia.

Effects of Methemoglobinemia on fingers and palm

- Large-scale urbanization has largely influenced the environment.
- A number of environmental episodes have adversely affected the environment. Some notable examples are the London smog (which killed about 4000 people) and many nuclear catastrophes, including the nuclear bombing of Hiroshima and Nagasaki during World War II (responsible for the death

London smog of 1952—a consequence of environmental pollution

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of thousands of people and disability of millions of people for the rest of their lives). The Bhopal gas tragedy, caused by the leakage of methyl isocyanate gas from the Union Carbide factory in Bhopal, India, on 2 December 1984, is the world's worst ever industrial disaster.

In view of the above, environment protection (a matter of primary importance to humans and their future) must be the top priority.

1.1 COMPONENTS OF ENVIRONMENT

The environment is composed of the following three main components.

- **Abiotic components:** light, humidity and water, temperature, atmospheric gases, altitude, latitude, and seasonal changes.
- **Biotic components:** plants (flora and fauna), animals (including human beings), parasites, and microorganisms.
- **Energy components:** solar energy, geothermal energy, water energy, and nuclear energy.

Utilization of solar energy

Geothermal energy

1.2 TYPES OF ENVIRONMENT

Environment can be basically categorized into natural and human-made environment. Natural environment comprises air, water, soil, solar radiation, land, forest, wildlife, flora, and fauna. Human-made environment includes housing, agricultural lands, industries, dams, and power plants producing hydro, thermal, and nuclear energy.

1.3 SEGMENTS OF THE ENVIRONMENT

The four basic segments of environment are (1) atmosphere, (2) hydrosphere, (3) lithosphere, and (4) biosphere. The cover of air that envelops the earth is known as the atmosphere. All the water on or over the surface of the

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earth constitutes the hydrosphere. It covers about 75% of the earth's surface, either as salt water or as fresh water, and includes oceans, seas, rivers, lakes, streams, and groundwater.

The layer of rocks that forms the outer part of earth is called lithosphere**.** It includes soil, earth, rocks, and mountains. The part of the earth's surface and the atmosphere in which plants and animals live is called biosphere. It comprises lithosphere, hydrosphere, and atmosphere.

1.4 CONSERVATION AND MANAGEMENT OF ENVIRONMENT

Conservation and management of the environment are of utmost importance for the survival of mankind. In this regard, the United Nations has identified five challenges for the world community: loss of biodiversity, climatic changes, water pollution, ozone layer depletion, and land degradation.

Loss of biodiversity is not reversible once a species becomes extinct; it is gone forever. For the conservation of biodiversity, a number of conventions, protocols, and acts have been formulated by various countries, which are discussed in Chapter 4.

The climate of any region is never constant; it keeps on changing. A number of factors are responsible for changes in climate. These include solar

Melting of glaciers due to climate change

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Contamination of river water by human disposables

energy, ocean and waterbodies, altitude, sea and land breeze, and human activities. In fact, human activities change the climate in a drastic way and at a much faster rate. This includes air pollution, which is also due to the release of greenhouse gases and the subsequent greenhouse effect. This results in global warming, which in turn causes melting of glaciers and flooding of low-lying areas. All these are discussed in Chapter 6.

Water pollution can occur in fresh water, marine water, and also underground water due to various pollutants finding their way into waterbodies. Polluted water is hazardous to human health. Water pollution

Main sources of chlorofluorocarbons, the pollutant responsible for depletion of the ozone layer

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has caused irreversible environmental effects, hardship for the poor, and losses in economy. All these are discussed in Chapter 5.

The stratospheric ozone layer provides a protective shield by absorbing most of the ultraviolet radiations that can harm living organisms on earth. Stratospheric ozone is constantly being created and destroyed by natural photochemical processes in dynamic equilibrium. This equilibrium is disrupted by various human activities by releasing anthropogenic chemicals, especially chlorine and bromine compounds, like chlorofluorocarbons (CFCs), halons, and a broad range of industrial chemicals used as refrigerants, foaming agents, aerosols, retardants, and fumigants. All these chemicals result in depletion of ozone layer. This permits more ultraviolet-B radiation to reach earth, resulting in skin cancer, cataracts and irreversible eye damage, and could also suppress the immune system. All these are discussed in Chapter 6.

Land degradation is attributed to human activities and is caused by desertification and deforestation. It is also central to global environmental progress. The environmental and economic consequences of land degradation are not only confined to countries where it occurs. It also leads to loss of biodiversity and pollution of international waters.

Most of the countries are adopting a variety of policies and measures to conserve biodiversity and prevent climate change and degradation of international waters. These include improved farming and grazing practices; afforestation, reforestation and forest management; and upgraded water management as policy reforms for better land-use policies. Management of the environment is the focus of Chapter 8.

Children planting saplings and promoting afforestation

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CHAPTER 2

Natural Resources

2.1 INTRODUCTION

Environment, as we know, means "surroundings" of an object. In fact, everything around us is our environment. While all living beings interact intimately with their environments, the interaction of human beings with the environment is maximum.

Our environment supplies us with various essential resources that are necessary for the sustenance of life. The three primary natural resources in the environment that are available to us are air, water, and land. In addition, we receive energy from sunlight, and other nutrients and minerals are found in plants and soil. Another important natural resource is the forest, which is the storehouse of a large number of important minerals. Natural resources meet most of our requirements regarding food, clothing, buildings, dams, and vehicles.

Man has exploited natural resources since the beginning of the civilization. Trends reflecting the exploitation of natural resources at the rates much higher than the rates at which these resources are replenished through natural processes are evident all over the world. Population explosion, considerable increase in per capita resource demand, and continuous industrial developments are widening the gap between exploitation and replenishment. All these have led to the disruption of the functioning of the natural environment.

The natural environment, which includes forests, grasslands, deserts, rivers, lakes, oceans, is the habitat for different communities of plants and animals. The interaction between abiotic and biotic components of nature is the basis of formation of various types of ecosystems. (For more details

Natural environment is a habitat for all flora and fauna

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about ecosystems, refer to Chapter 3.) A number of organisms are our food resources.

2.2 TYPES OF NATURAL RESOURCES

Natural resources are of two types: renewable and non-renewable natural resources. Renewable resources get renewed or replenished in a reasonable time and are not likely to be exhausted by human consumption. Air, sunlight, and water are examples of such resources. Other examples of renewable natural resources are oxygen and nitrogen. Oxygen present in the air is replenished by photosynthesis; in a similar way, nitrogen gets constantly renewed.

Non-renewable resources cannot be replenished within a reasonable time. Examples of such resources include coal and diamond, which take millions of years for formation and will get exhausted. Figure 2.1 gives an account of renewable and non-renewable natural resources.

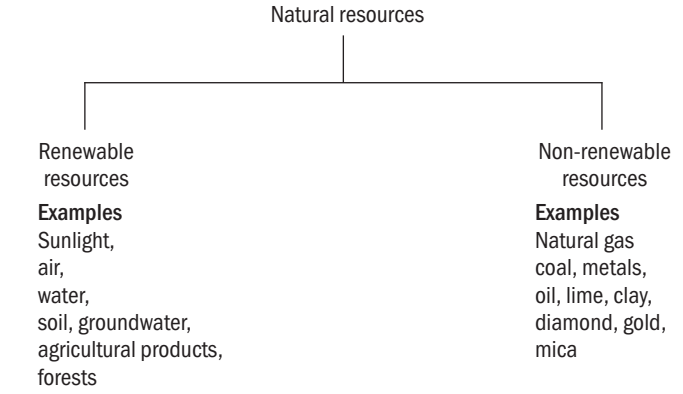

Figure 2.1 Various types of renewable and non-renewable natural resources

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2.2.1 Earth's Resources and Mankind

Mankind is dependent on four basic environmental segments: atmosphere, hydrosphere, lithosphere, and biosphere.

Atmosphere

The region of air present above the earth's surface is called the atmosphere. It extends up to a height of about 500 km from the earth's surface. The atmosphere consists of a number of gases which are detailed in Table 2.1.

Table 2.1 Composition of air near sea level

Component	*Amount*	
	% by volume	*ppm*
Major components		
Nitrogen (N_2)	78.08	780 900
Oxygen (O_2)	20.94	209 400
Water vapour (H_2O)	0.15	1 000–50 000
Minor components		
Argon (Ar)	0.934	9 340
Carbon dioxide (CO_2)	0.032	320
Trace components		
Neon (Ne)	0.00182	18.2
Helium (He)	0.00524	5.24
Methane (CH_4)	0.00018	1.8
Krypton (Kr)	0.00018	1.1
Nitrous oxide (N_2O)	0.000025	0.25
Hydrogen (H_2)	0.00005	0.5
Xenon (Xe)	0.0000087	0.087
Sulphur dioxide (SO_2)	0.0000002	0.002
Nitrogen dioxide (NO_2)	0.0000001	0.001
Ammonia (NH_3)	0.000001	0.01
Carbon monoxide (CO)	0.000012	0.12
Ozone (O_3)	0.000002	0.02
Iodine (I_2)	Traces	Traces

Note The values in parts per million (ppm) are obtained by multiplying the per cent volume by 10^{-4}.

Out of the various gases present in the atmosphere, the most prominent are oxygen and carbon dioxide. Carbon dioxide is also responsible for the greenhouse gas effect (refer to Chapter 6). Oxygen is used for human respiration (metabolic requirement).

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In fact, no life can survive without oxygen. It is produced in the air by the reaction between carbon dioxide and water in the presence of sunlight and chlorophyll (during photosynthesis, green pigments of plants produce carbohydrates, which are used by plants as their food and oxygen).

The temperature of the atmosphere varies from −92°C to 1200°C, depending on its height from the surface of the earth. The atmosphere is divided into four regions as given in Table 2.2.

Table 2.2 Regions of the atmosphere

Region	*Height range (km)*	*Temperature range (°C)*	*Main chemical constituents*
Troposphere	0–11	15–56	N_2, O_2, CO_2, H_2O
Stratosphere	11–50	56 to –2	O_3
Mesosphere	50–90	– 2 to –92	O_2^+, NO^+
Thermosphere	90–500	–92 to 1200	O_2^+, O^+, NO^+

Among these regions of the atmosphere, stratosphere is most important (Figure 2.2). It contains a layer of ozone, which absorbs harmful ultraviolet (UV) radiation from the sun. The UV radiations are known to cause cancer. The solar energy reaching the earth is absorbed by the earth's surface increasing its temperature. The rest of the heat radiates back to the atmosphere. Some amount of the heat is trapped by the greenhouse gases (such as carbon dioxide and methane) leading to global warming (refer to Chapter 6).

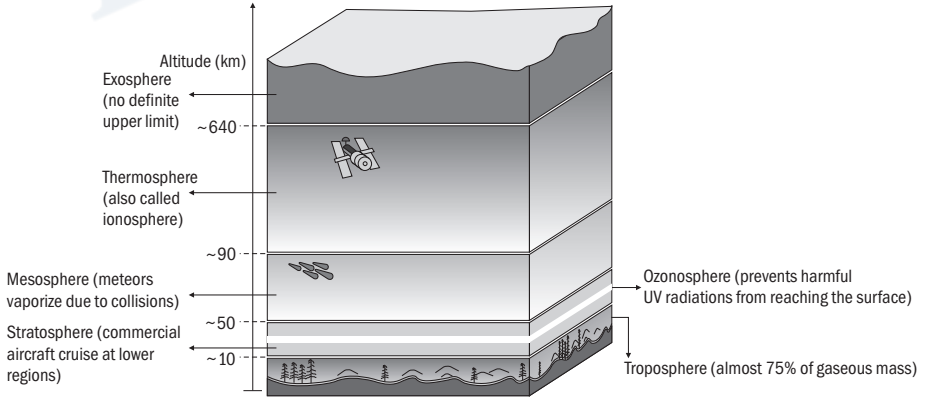

Figure 2.2 Different layers of the atmosphere

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Living creatures cannot survive without air even for a few seconds. Since air is essential for survival, it must be kept clean and free of pollutants. Various pollutants such as oxides of carbon, sulphur, and nitrogen are discharged into the atmosphere through industrial waste units and by burning of fuels in automobiles and power-generating units. In fact, growing number of automobiles such as scooters, motorcycles, cars, buses, and trucks that run on fossil fuel (petrol and diesel) is the major cause of air pollution in cities. Air pollution severely affects human health; it is responsible for acute and chronic respiratory problems such as lung infections, asthma, and even cancer. It is also responsible for acid rain (refer to Chapter 6).

Hydrosphere

The hydrosphere covers about two-thirds of the earth's surface, which may indicate that the supply of water on our planet is inexhaustible. In fact, oceans alone account for 97% of earth's water supply, which cannot be used for human consumption and other activities such as agriculture due to its high salt content. Of the remaining 3%, about 2% is blocked in the polar ice caps and glaciers and only about 1% is available as fresh water in rivers, lakes, reservoirs and as groundwater. In fact, this 1% of the total water is suitable for human consumption, agriculture, and industrial set-up.

Clean water is used for drinking; it is a metabolic requirement for all living processes. In addition, water is used for washing, cooking, agriculture, and industry. Water flowing down from mountainous ranges is harnessed to generate electricity (hydro energy).

It is apprehended that there will be serious crisis of clean water all over the world, if existing supplies are not properly harnessed, wastage is not avoided, and pollution is not checked. Water pollution not only changes the physical properties of water such as its colour, taste, temperature but also makes it acidic, alkaline, or saline due to the presence of dissolved or suspended chemical substances. Contamination of water with toxic substances such as arsenic, cyanide, ammonia, mercury, lead, phenol, pesticide makes it harmful for use by human beings. Some of these substances are also the cause of many diseases such as cholera, typhoid and dysentery. Millions of people all over the world, particularly in the developing countries, lose their lives every year from water-borne diseases. Water gets polluted by the discharge of industrial wastes, sewage, domestic wastes, and discharge of agrochemicals into waterbodies. Another cause of water pollution, particularly marine pollution, is the petroleum spills in the waterbodies due to accidents of oil tankers.

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Lithosphere

Earth, the third planet in the solar system, is the only planet that supports life. The upper 400 km of the solid earth is called the lithosphere. Lithosphere means the mantle of rocks constituting the earth's surface. Rocks are subjected to continuous processes of physical, chemical, and biological weathering. The resulting primitive soil is colonized by higher plants. Soil (or the topsoil as it is generally called) plays a very important role in the lives of human beings and animals as it produces food for them. However, human activities cause soil pollution. The pollutants include pesticides, fertilizers, particulate matter, industrial wastes, sewage, and domestic wastes.

Fertilizers contaminate freshwater and marine ecosystems

Contamination of groundwater due to sewage

Removal of topsoil degrades land

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The uppermost layer of the soil is vital because all the nutrients required by plants are present in this layer. Removal of the topsoil, that is soil erosion, is a natural process and is evoked by wind, water, ocean waves. Activities such as felling of trees, overgrazing, overcropping, and improper tilting accelerate soil erosion.

Biosphere

In biosphere, water, atmosphere, and many smaller ecosystems coexist and operate. Biosphere consists of three main subdivisions: lithosphere (land), hydrosphere (water), and atmosphere (air) or the gaseous envelope of the earth that extends up to a height of 22.5 km. Biosphere can be represented as shown in Figure 2.3.

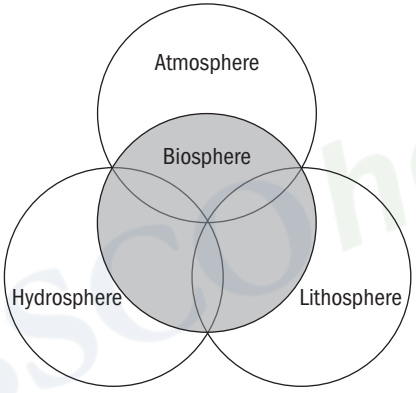

Figure 2.3 Representation of biosphere (shaded portion)

Biosphere is the area of contact and interaction between the three components: lithosphere, hydrosphere, and atmosphere. This area is extremely important as the entire life is confined here, and the basic processes of life such as respiration and photosynthesis take place in it (Figure 2.4). Living organisms are mostly confined to the parts of the biosphere that receive solar radiation during the day. Sun is the source of energy for life within the biosphere, without which the biosphere will collapse. Air, water, and soil supply the necessary nutrients for living organisms, which are recycled over and over again for life to continue.

Biosphere provides food for all forms of life (in the form of crops and domestic animals) and produces food chains in nature on which human beings are dependent. The biomass fuelwood from forest along with other forms of organic matter is used as a source of energy. The timber from forests is used for construction purposes.

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All the four spheres, that is, the atmosphere, hydrosphere, lithosphere, and biosphere, are intimately interlinked and dependent on each other. The interdependence is mainly in the form of various cycles such as water cycle, oxygen cycle, nitrogen cycle and energy cycle (refer to Chapter 3).

In the hydrological or water cycle, water evaporates from the hydrosphere (seas and waterbodies) and forms clouds in the atmosphere. This cloud condenses and falls in the form of rain. Rain provides moisture for the lithosphere, which is essential for life processes. Also, the action of air on rocks results in the weathering of rocks, leading ultimately to the formation of soil in which plants grow.

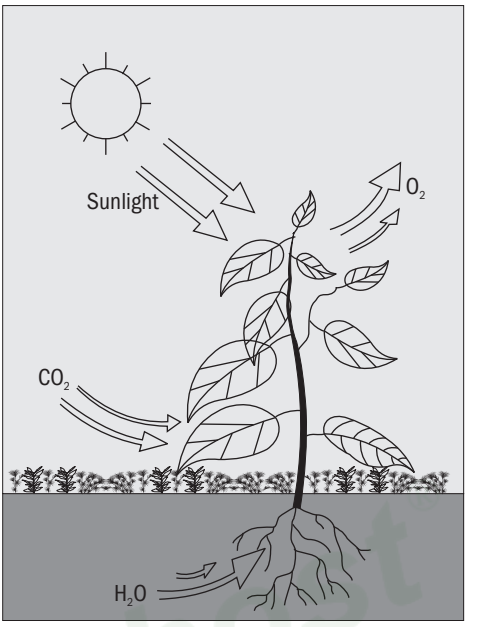

Figure 2.4 Process of photosynthesis in plants

2.3 RENEWABLE AND NON-RENEWABLE RESOURCES

As discussed earlier, there are two types of natural resources: renewable and non-renewable.

The ecosystems in the biosphere function as resource producers. The driving force of ecological systems is the solar energy, which helps in the growth of plants in forests, grasslands, and aquatic ecosystems. The forest ecosystem recycles its plant materials by returning dead plant matter to the soil. In grasslands, the recycling of material is much faster because grass dries up every year after the rains. Solar energy also regulates life in the aquatic ecosystems and is responsible for the hydrological cycle.

Our requirement of food is met mostly by supply from agricultural ecosystems. Although such ecosystems are dependent on rainfall, use of agrochemicals such as fertilizers and pesticides help in increasing production. However, modern methods of agriculture using agrochemicals are responsible for a variety of environmental problems leading to the formation of

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unproductive land. The modern irrigation procedures lead to the development of salinity in soil. In addition, pesticides pose health problems for humans.

Various industrial units that produce consumer products need raw materials, including water, minerals, and power. The industrial processes release large amount of gases and waste products into the environment leading to pollution. This can be avoided if the industries are properly managed to check on their effluents and treat their wastes.

2.3.1 Problems associated with Natural Resources

The main problem associated with natural resources is their unequal consumption. A major portion of the natural resources is consumed by advanced or developed countries. Certain other regions such as India and China are also responsible for consumption of a good percentage of resources, which can be attributed to the increase in population of these countries. A good indicator is the per capita consumption of natural resources in a country. Consumption of resources per capita in developed countries is about 50 times greater than in most developing countries. This is also associated with production of over 75% of the global industrial wastes and greenhouse gases in developed countries. As an illustration, USA alone, with only about 4% of the world population, consumes about 25% of the world's resources.

Production of animal food (non-vegetarian diet) for human consumption requires more land than for growing crops and vegetables. Thus, it can be said that countries that depend more on non-vegetarian diets need much larger area as pastureland than where people are mainly vegetarian. Such a problem does not exist for nations that depend on seafood.

Land as a resource is under serious pressure due to its increased demand for various purposes. Land is necessary for food production, animal husbandry, industrial units, and ever-growing needs of growing population for settlements. It is essential to evolve a rational land policy keeping the various requirements in mind. Land and water resources also face the acute problem of being polluted mostly by industrial wastes and rural and urban sewage. Deforestation is the most alarming problem arising due to the excessive use of land. Depletion of forests affects the oxygen level in the atmosphere and removal of carbon dioxide. Deforestation leads to decreased supply of food, fuel, timber, fodder, medicinal plants. This loss is beyond repair. Thus a well-planned forest policy needs to be developed. If required, the trees in forests should be felled in phases so that the place from where the trees are cut can be redeveloped by plantation.

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2.3.2 Non-renewable Resources

The most important non-renewable resources are fossil fuels such as coal, oil, and natural gas. In addition, minerals are also non-renewable resources.

Coal

Coal reserves have been derived from prehistoric forests through the processes of decaying and transformation. Coal was formed from the remains of trees and ferns that grew in swamps some 500 million years ago. Initially, bacterial decomposition and chemical action on such plant debris produced peat (dead plant material) as an intermediate product. Peat is composed of dead leaves, stems, and roots of plants; it mainly consists of cellulose. As a result of high pressure and temperature during geological changes under the earth's surface, peat was transformed into coal. Following are the sequence of changes that took place for the formation of coal (Figure 2.5).

Dead plant material, or peat

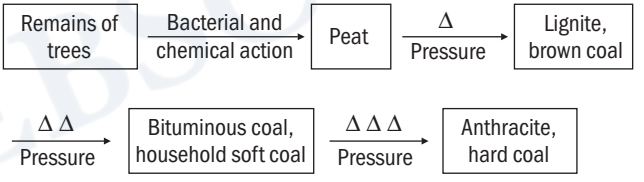

Figure 2.5 Process of formation of coal

Coal has been a major contributor to world's energy needs. In India, about 30% of energy needs are met through consumption of coal. The major consumers of coal are the power, steel, cement, railways, fertilizer, and household sectors.

In India, coal reserves are substantial constituting about 5.7% of coal reserves in the world. Direct combustion of coal causes major air pollution. Gases produced from combustion of coal such as oxides of carbon, nitrogen, and sulphur are toxic and pollute the atmosphere. Besides, the coal industry is responsible for the ill-health effects of the community, especially the workers working in such plants.

If used or consumed at the present rate, the coal reserves will be completely used up.

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Petroleum

At present, petroleum is the major contributor to the world's energy pools. Petroleum is an oily, thick, and generally dark-coloured liquid. It is found deep below the earth's crust trapped within the rock structure. The origin of the word "petroleum" is from the Latin words "petra" (meaning rocks) and "oleum" (meaning oil). Petroleum is believed to have been formed by the decay of the remains of ancient microscopic marine plants and animals which were buried under the layers of rock and clay over millions of years. Since petroleum occurs at a depth of 500–600 km below the surface of the earth, it is obtained by the drilling process. The most important aspect is to locate the oil fields for which scientific methods are now available. Once the drill strikes the oil, the underground pressure of the gas (known as petroleum gas or natural gas) forces the oil to come out to the surface.

Offshore drilling of petroleum

Nowadays, petroleum is also obtained by drilling into the sea bed. In India, the procedure is used for producing crude oil from Bombay High. The petroleum thus obtained is separated into various fractions at different stages of fractional distillation. The various fractions obtained are given in Table 2.3.

Table 2.3 Fractions obtained from petroleum refining

Fraction obtained	*Temperature range*	*Uses*
Petroleum gas	Up to 25°C	Used as fuel. Liquefied petroleum gas (LPG) is used as domestic gas and also for running automobiles.
Petroleum	30–80°C	Used as solvent for the extraction of oils and fats in the industry
Gasoline or petrol	80–170°C	Used as motor fuel, aviation spirit, and also for dry-cleaning
Kerosene oil	170–250°C	Used as a fuel for stoves, for lamps as an illuminant, and as fuel for jet aircraft engines
Diesel oil	250–350°C	Used as fuel for high-speed diesel engines in trains, buses, and cars
Fuel oil	350–400°C	Used for making lubricating oil, paraffin wax, and asphalt
Petroleum coke	Residue	Used for heating purposes

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Petroleum oil, if it is continued to be used at the present rate, is not expected to last too long. So it must be used judiciously and alternative fuel should be used for the same purpose.

Natural gas

The gas that flows out of naturally occurring oil wells is referred to as natural gas. In many parts of the world, natural gas is found in association with petroleum. Some wells produce only natural gas, and no petroleum oil. Natural gas, like petroleum, is also believed to have originated from the decomposition of organic matter trapped in the layers of sedimentary rocks.

An autorickshaw running on compressed natural gas

In India, natural gas industry is in its infancy and is largely derived from the cracking units of petroleum refineries. It occurs in large amounts in Bombay High, the Gulf of Cambay, and Ankleshwar in Gujarat. New gas fields have been found in Tripura, Jaisalmer and Krishna–Godavari delta.

About 7% of India's natural gas stock is used especially in power generation, fertilizer and petroleum production. Natural gas can reduce dependence on foreign oil. Nowadays, natural gas is used in the form of compressed natural gas (CNG) for automobiles, particularly for taxis and buses.

Pollution caused by burning of fossil fuels

Fuels such as coal, wood, petrol, diesel, and kerosene are used in homes, industry and transport. Although these fuels meet our energy needs, the products of their combustion cause severe air pollution. Table 2.4 lists the various pollutants, their sources, and harmful effects.

Mineral resources

Minerals are natural substances obtained from earth by mining. These are the backbone of our industries and are of commercial and economic use. Nowadays, minerals such as uranium are used for generating energy; thus, they can be considered an alternative source of energy. A number of minerals such as iron, copper, aluminium are indispensable to meet our day-to-day

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Table 2.4 Pollutants obtained from burning of fossil fuels

Pollutants	*Source*	*Effects*
Carbon monoxide*	Combustion of coal and petrol	Toxic gas
Carbon dioxide	Combustion of coal and petrol	Carbon dioxide is a non-toxic gas. However, excess of carbon dioxide in the atmosphere is considered a pollutant since it produces greenhouse effect and is also responsible for global warming
Sulphur dioxide#	Combustion of coal and petrol	Causes suffocation and affects lungs
Oxides of nitrogen# Nitric oxide and nitrogen dioxide	Combustion of coal and petrol	Both are toxic, but nitrogen dioxide is more harmful. It is harmful for both humans and plants
Particulate matter×	Combustion of both coal and petrol	Affects lungs

Notes

* Carbon monoxide is a deadly, poisonous gas. On inhaling, it combines with haemoglobin in blood and restricts transport of oxygen by blood to other parts of body tissues. This leads to respiratory problems, suffocation, and even death.

\# Both sulphur dioxide and oxides of nitrogen react with air and moisture in the atmosphere to produce sulphuric acid and nitric acid. These are responsible for acid rain.

× Particulate matter gets deposited in the lungs and is responsible for a number of health problems, including tuberculosis.

requirements. India is self-sufficient in about 35 minerals, which are used as raw materials for basic industries. Iron, aluminium, and phosphates, which are available here, are used for making phosphate fertilizers. For some non-ferrous metals such as copper, zinc, and lead, we depend on imports from other countries.

Minerals are found in limited quantities and can be exhausted. At the present rate of consumption, a number of these minerals may not last for long. Therefore, it is best to conserve the mineral resources.

Minerals meet our daily requirements

Iron Copper Aluminium

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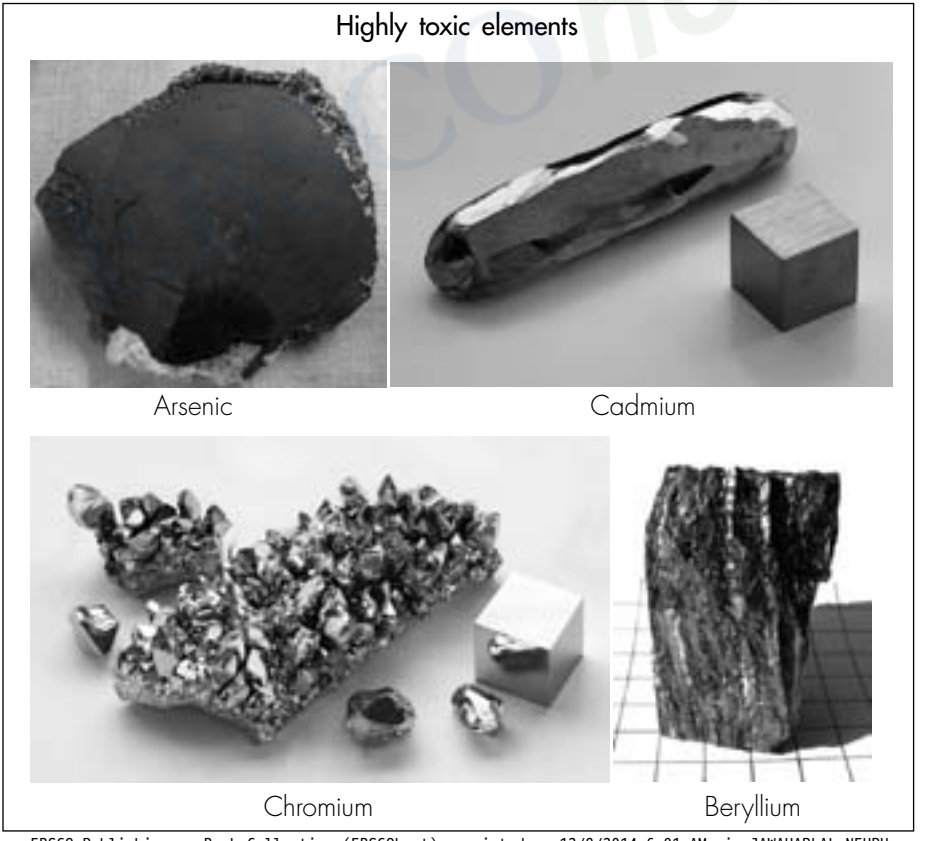
Conservation means that there should be judicious use with minimum wastage. One way of minimizing or reducing waste is recovering as much as possible and leaving nothing to waste. The recovered materials can be reused after processing. The scraps of used metals can be recycled or used again. This will reduce the demand of many mineral reserves. The alloys of magnesium are fast replacing steel and are reducing the demand for copper, lead, and tin, which are in short supply. Substitutes for metals such as mercury, gold, silver, platinum and also for asbestos are urgently needed.

One drawback of mining of minerals is that the area after mining becomes useless. In fact, it remains barren and does not permit growth of any vegetables. Such lands can be covered with fresh topsoil; use of fertilizers, sewage waste, domestic or municipal waste, farmyard manure will go a long way in restoring the fertility of these degraded and barren lands.

Some elements such as arsenic, cadmium, beryllium, chromium, lead, manganese, mercury, selenium, and zinc are extremely toxic in nature. In case the industrial units using such metals discharge their metallic wastes into waterbodies, this can have far-reaching consequences on the health of aquatic



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organisms and also on those human beings who consume such organisms. It is best for the industries to treat their wastes at the site of generation and discharge only the harmless parts onto land or waterbodies.

2.3.3 Renewable Resources

Natural resources that can be replaced from time to time by natural processes are called renewable resources. The most common renewable resources include air, water, land, forest, food, and energy.

Air

We know that air (or the atmosphere) is present in abundance. As we do not use air (except in some chemical processes), there is no question of its replacement. Maintaining its quality (purity) and composition is more important, where the ratio of oxygen to nitrogen in air is 1:4. In a similar way, the percentage of carbon dioxide in the atmosphere is about 0.032% by volume. If there is shortage of carbon dioxide, there will be shortage of oxygen too because oxygen is produced from carbon dioxide by photosynthesis. On the other hand, the presence of excess carbon dioxide causes greenhouse effect and global warming.

It is most important that air should be free of pollutants basically the oxides of carbon, nitrogen, and sulphur that are discharged into the atmosphere by industrial units using coal and petrol. Automobiles are a major contributor of these oxides.

Necessary precautions should be taken so as to restrict the amount of various pollutants in air to a bare minimum.

Water

The most essential requirement of life is water. Although water is available in appreciable amounts (particularly in oceans and seas), there is a scarcity of usable water in the world.

The importance of water is evident from the fact that many early civilizations had flourished on river banks. Fresh water is one of the most important components for sustaining human life. It is one of the five important elements—earth, fire, air, space, and water.

Modern developments and mismanagement of water resources during the past two decades have resulted in significant water shortage. For a large number of population, shortage of water means epidemic, hunger, despair, and death.

Less than 3% of total water is fresh water and, only one-fifth of this fresh water is available in usable liquid form. Again more than 90% of this

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scarce commodity is in the form of groundwater while only 1% is available in lakes and ponds. India also is fortunate in terms of total annual rainfall, which is another resource of fresh water.

It is essential that the world must rethink about the overall management of water resources. The world's population has crossed the 6 billion mark, and the demand for fresh water has increased. On the basis of various studies conducted, it is estimated that a person needs a minimum of 20–40 L of water per day for drinking and sanitation. This has placed enormous demands on the world's limited supply of fresh water. It has been found that more than 1 billion people worldwide have virtually no access to clean water. The scarcity of clean water has led to many conflicts. For example, in India, Karnataka and Tamil Nadu are fighting over the waters of the Cauvery river, and Karnataka and Andhra Pradesh are fighting over the waters of the Krishna river.

With ever-increasing human population, there is a growing need for larger amount of water to fulfil the basic needs. This increased requirement cannot be met in many parts of the world. In fact, over-utilization of water occurs at various levels. A large number of people use more water while taking bath using a shower or during washing clothes. Some agriculturists use more water than is necessary to grow crops. A number of procedures exist by which farmers can use less water without any reduction in crop yields,

Drip farming method helps conserve water

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such as use of sprinklers for watering plants and grass. Use of drip farming method is also very advantageous. In this procedure, water is allowed to fall in the form of drops near the roots of the plants.

Industries use enormous amount of water for various stages. The used water is discharged into waterbodies. Industries, to maximize short-term gains, do not process the discharged water for reuse, since it involves costs.

In most of the arid regions of the world, rains are unpredictable. This results in periods when there is acute scarcity of drinking water. Although it is not possible to prevent the failure of monsoons, its ill effects can be reduced by proper environmental management. Drought conditions also lead to food shortages and malnutrition especially in children.

It is necessary to make people aware of "save water" campaigns. In fact, not a drop of water should be used unless it is necessary. The following points can be helpful in saving water.

- Effective rainwater harvesting in urban environment
- Reduction of water wastage in agriculture by using drip irrigation
- Prevention of leakage of water from taps and municipal pipe lines
- Pricing of water at its real value so that people use it judiciously and reduce wastage
- Prevention of water pollution

Rainwater harvesting prevents wastage of water

The sources of water pollution caused by human activities include the following.

- Domestic effluents
- Industrial effluents
- Surface run-off
- Waste heat

All necessary precautions should be taken to ensure that the fresh water in rivers, ponds, lakes is not polluted.

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Land

Land is the basic resource and the foundation on which the entire ecological system rests. It is the living ground (habitat) for all terrestrial plants and animals. Land is considered a renewable resource if it is properly utilized or managed. However, if it is loaded with highly toxic and industrial and nuclear wastes, it becomes a non-renewable resource.

The capacity of the land to support life and other activities of man and animals is dependent on its biological productivity and the load-bearing capacity of soil and rocks. Due to increase in population, land is under great pressure. Mismanagement of land resource due to indiscriminate cutting of trees or deforestation has caused considerable damage to the quality of soil. As on date, the per capita land resource available in India is less than 0.27 hectares, which is likely to go down to 0.18–0.16 hectares by 2025.

The land on earth is as limited as any other natural resource. Human beings use land for building homes, cultivating food, maintaining pastures for domestic animals, and developing industries to provide goods; towns and cities are created for supporting the industries. It is equally important for humans to protect wilderness areas in forests, grasslands, wetlands, and mountains to maintain our critically valuable biodiversity. In view of all this, it is necessary to adopt a rational use of land policy, taking care to maintain the protected areas (national parks and wildlife sanctuaries).

Forests, grasslands, wetlands, and mountains are biodiverse natural habitats

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Soil forms the uppermost layer of the land. It is the most precious of all reserves since it supports the whole life system, provides food and fodder in the form of vegetation, and also stores water. Soil contains sand, silt, and clay mixed with air and moisture and also rich organic and mineral nutrients.

It takes nature around 50 years to build a centimetre of the top soil. Each year, about 6000 million tonnes of soil all over the world are eroded. This involves loss of about 2.6 million tonnes of nitrogen and 3.3 million tonnes of phosphorus. The best way to prevent soil erosion is by providing adequate tree and grass cover. Alternatively, we should resort to counter building and gully-plugging on scientific lines, followed by planting green manure shrubs and trees on field buds. In India, the commonly used green manure crops are sun lump, dhaincha, cluster-bean, sengi, cowpea, horse gram, berseam, and lentil.

The Eravikulam National Park, Kerala

The Namdapha National Park, Arunachal Pradesh

In arid and semi-arid regions, too little or too much irrigation can lead to the formation of saline or alkaline soil. The alkalinity is due to increase in soluble salts. The most effective treatment of alkaline soils is to apply "gypsum". A good drainage system must also be provided to assist in the washing out of the sodium from saline salts. Such salts are useful for growing most salt-tolerant species.

Use of excess fertilizers or improper use of pesticides can pollute the soil, thereby inhibiting plant growth. Also, the run-off from agricultural fields leads to the discharge of pesticides and fertilizers into waterbodies leading to severe problems.

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Forests

Forests are our national treasures. They provide us with a wide variety of commodities such as timber, fuelwood, fodder, fibre, fruits, herbal drugs, cosmetics, and many types of raw materials used by industries. Forests provide abode for the wildlife, check air pollution, and play a vital role in the economy of a nation. In fact, forests are indispensable for human beings.

Forests are being depleted rapidly due to increased population and human activities. Deforestation not only diminishes the natural beauty of a place but also disturbs the ecological balance of that place. It has been estimated that an area of tropical forest four times the size of Switzerland disappears every year. In India, about 12% of its land have been estimated to be under forest, which ideally should have been 33% of the land. Moreover, the hillsides in the country have been stripped off their vegetation cover in the Himalayas, which is a major cause of avalanches and landslides.

Food

We are dependent on our food resources which are primarily based on agriculture, animal husbandry, and seafood. The most important crops are wheat, rice, maize (corn), potatoes, barley, and oats. Other less important foods include sweet potato, sugar cane and beet, pulses (legumes), sorghum and millet, vegetables and fruits, and milk products.

The three primary crops on which the majority of the mankind depends for its nutrients and calorie requirements are wheat, rice, and maize. Wheat and rice are the staple food for most of the people. Potatoes, barley, oats, and rice are staple in mountainous regions and high altitudes since they grow well in cool and moist climates. Cassava, sweet potatoes, and other roots and tubers need warm and wet areas for growth. Sorghum and millet are drought resistant and so are used as staple food in dry regions of Africa.

Although meat and milk are very nutritious, their distribution is unequal across the globe. Fish and seafood are a good source of high-quality proteins.

Most conmonly used green manure crops in India

Dhaincha Cluster-beans Cow peas

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A major cause of avalanches and landslides is lack of vegetation

These account for about 75% of the world's protein consumption as compared to land animals.

On the basis of various studies, it has been found that we have already surpassed the sustainable harvest of fish from most of the world oceans. There is a danger of seafood being contaminated by poisonous heavy metals such as cadmium, lead, and mercury which are discharged into waterbodies as industrial wastes. The consumption of such seafood leads to a number of health hazards in humans. There is a great potential of raising fish and crustaceans in ponds under controlled conditions. Even environmentally sensitive fish such as trout can be raised in high-density ponds. Genetic engineering techniques are being used to breed special types of fish in increased yield just as the Green Revolution has done for crops.

India is self-sufficient in food production. This is the result of the Green Revolution of the 1960s in which more inorganic and organic fertilizers and other agrochemicals were used. All this was possible by using genetically engineered crops. The Green Revolution of the 1960s, no doubt, reduced the starvation in the country. Many of the techniques that have been used are now being questioned. Some of these are as follows.

- Fertile soils are being exploited faster than they can recuperate.
- Forests, grasslands, and wetlands have been converted into agricultural lands. This has led to serious ecological problems.
- Most farmers grow single crops (monoculture). If a crop is hit by a pest, the entire crop can be destroyed.

If traditional varieties are used and several different crops are grown, the chance of complete failure is decreased considerably. The use of harmless alternatives to inorganic pesticides and fertilizers has been proved to be the best. This is known as integrated crop management. As far as possible, agriculture should be sustainable. According to the Food and Agricultural Organization (FAO), sustainable agriculture conserves land, water, plant,

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and animal genetic resources, does not degrade the environment, and is economically viable.

Uranium is an abundant source of nuclear energy

Energy

There are two sources of energy: renewable energy sources (also known as non-conventional energy sources) and non-renewable energy sources (also known as conventional sources of energy). Renewable energy sources include solar energy, hydro energy, tidal energy, wind energy, biomass energy. Non-renewable energy sources include fossil fuels, coal reserves, petroleum, and natural gas. Another important energy resource includes radioactive minerals, particularly uranium (^{235}U). Radioactive minerals produce nuclear energy or atomic energy.

The demand of energy approximately doubles every 14 years. Energy consumed by a country is considered one of the indicators of development of that country. India, with about 16% of the world's population, consumes only about 2% of the total energy produced in the world. This is in total contrast to USA that has only 6.25% of the world's population but utilizes 33% of the energy produced in the world. This gives us an idea about the low level of our development and should be an incentive for generation of more energy to meet our growing energy demand. Even today, about 80% of our population continues to depend on fuelwood, dung, and agricultural wastes for their energy needs. It is well known that the non-renewable sources of energy such as fossil fuels, coal, petroleum, and natural gas may not last for long. Forests are also being depleted at a faster rate due to indiscriminate felling of trees. In view of all this, it has become necessary to think about alternative, non-conventional sources of energy as described in Figure 2.6.

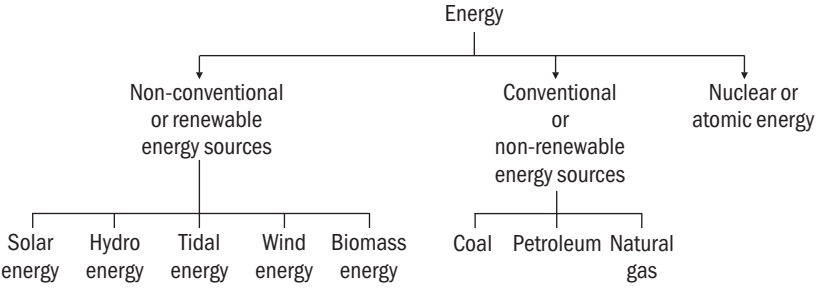

Figure 2.6 Types of energy sources

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Non-renewable energy resources

Non-renewable energy resources are natural resources that exist in fixed amounts and cannot be regenerated as fast as they are consumed. These are formed in the environment over long periods of time (even millions of years). With rapid increase in human population and rapid industrialization, these resources are likely to be exhausted before long. In view of this, efforts must be made to develop renewable sources of energy. Fossil fuels (coal, natural gas and petroleum), metals, and minerals are examples of such resources.

Renewable energy resources

In nature, we have plentiful supply of renewable energy resources that can be reproduced and harvested continuously. Solar energy, wind energy, water energy in the form of hydroelectric and tidal energy are being harnessed more efficiently nowadays. Renewable resources also include firewood or fuelwood obtained from forests and agricultural wastes such as biogas and animal dung. However, firewood or fuelwood cannot be harnessed in short time intervals, the reason being that once the trees are cut, they take a long time to grow. However, with proper planning of the forest system, more or less continuous supply of fuelwood (in reasonable quantities) can be maintained.

1. Solar energy

Solar energy is the most readily available in abundance. It is free as it does not belong to anybody. It is also non-polluting. Solar energy has the greatest potential of all sources of renewable energy. Until now, only a small amount of this form of energy could be used; it can become one of the most important supplies of energy, especially when other sources in the country are being rapidly depleted.

It has been estimated that the sun gives 1000 times more power than required. If we can use even 5% of this energy, it will be 50 times what the world will require.

Solar energy powered devices

Solar cooker Solar water heater Solar refrigerator

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Solar energy is being used in many parts of India for cooking through the use of "solar cookers".

Solar energy can be used directly to heat water during winter. This procedure is used in hotels and industrial establishments to get hot water.

Refrigerators run by solar energy have been developed for rural areas. They keep vegetables and fruits fresh for a longer period. There is great potential for using solar energy for cold storages. It can also be used for room heating in colder regions. These days, high-rise and multistorey buildings use more glass in buildings to trap sun's heat. This has lot of potential even in less sunny climates.

Solar energy can be used to produce electricity with the help of "photovoltaic cells" for driving vehicles, and for illumination. In solar facility, hundreds of mirrors are used to focus sun's energy on a central collector, which in turn attains extremely high temperatures; these are useful for production of electricity or for industrial applications. Solar energy can also be used to produce fire.

Some large industrial establishments in India are carrying out a coordinated programme of research in solar energy. This could be a suitable, environment-friendly source of power.

2. Hydro energy

Hydro energy is the cheapest, cleanest, best source of energy. Water power is developed by allowing water to fall under the force of gravity and is used almost exclusively for generation of electric power. Potential energy of water is converted into mechanical energy by using prime movers known as hydraulic turbines. Hydro energy is inexpensive at places where water is available in abundance. Although the capital cost of hydroelectric power plants is higher compared to other types of power plants, their operating costs are quite low, as no fuel is required (Figure 2.7).

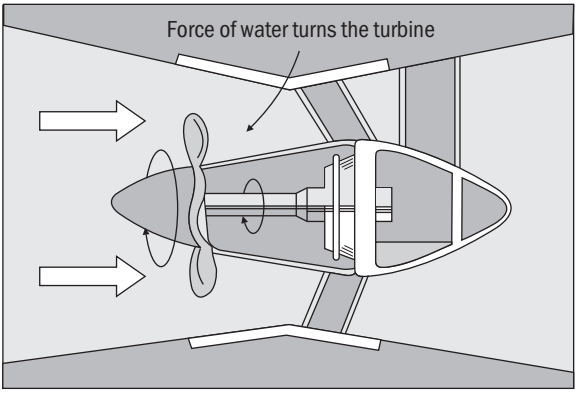

Figure 2.7 Schematic of a turbine engine

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However, obtaining electricity from mega dams has given rise to many controversies in recent times; small hydro plants are emerging as viable alternatives. These plants serve the energy needs of remote and rural areas where the grid supply is not available.

A natural or artificial waterfall is made to turn a modern type of pedal wheel, called a turbine, which upon rotation, generates electricity.

3. Tidal energy

Tides in the sea are the result of universal gravitational effect of heavenly bodies such as the sun and moon on earth. Tides can be used to produce electric power, which is known as tidal power. The use of tides for the generation of electric power is possible only in a few favourably situated sites where the geography of an inlet or bay favours the construction of a hydroelectric plant.

In 1960, a tidal plant was constructed in France having a rating of 240 MW. In India, the first tidal energy project with a capacity of 150 MW was set up at Vizhinjam near Thiruvananthapuram. A major tidal wave power project costing ₹50 000 million is proposed to be set up in the Gulf of Kutch in Gujarat. Other suggested sites for tidal power plants are the Gulf of Cambay and the Sundarbans areas of West Bengal. Figure 2.8 provides the structure and functioning of a tidal power station. Both incoming and outgoing tides are held back by a dam. The difference in water levels generates electricity in both directions as water runs through reversible turbogenerators.

4. Wind energy

Wind energy has been used for sailing, grinding grains, and irrigation for hundreds of years. Energy in wind can be economically used for generation of electrical energy and has great potential as a good energy source. The energy available in the wind over the earth's surface is estimated to be 1.6×10^7 MW, which is equivalent to the present energy consumption in the world. Wind is used to run a windmill, which in turn drives a generator to produce electricity.

Wind can also be used to generate mechanical power, such as pumping water. Windmills for water pumping have been installed in many countries, particularly in rural areas.

In India, generally wind speeds are in the lower ranges. Attempts are being made to develop low-cost, low-speed windmills for irrigation of small and marginal farms and for providing drinking water in rural areas. Wind speeds are high in coastal areas of Saurashtra, Western Rajasthan, and

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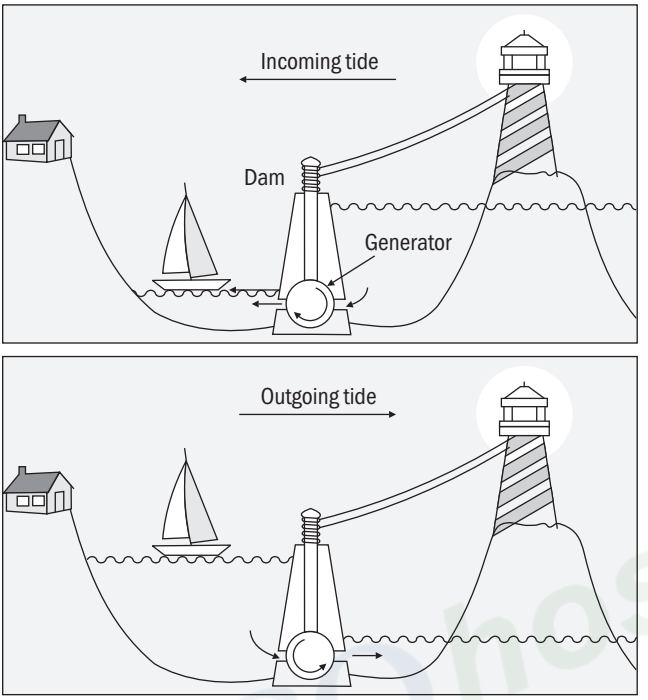

Figure 2.8 Representation of a tidal power station

Central India. In these areas, medium- or large-sized windmills could be set up for generation of electricity.

Windmills were first employed for producing energy in 1973

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Wind energy is an eco-friendly power source. It is a renewable source of energy, is non-polluting, and does not need any fuel consumption. It works up to a few kilowatt system and is less costly on a small scale.

5. Biomass energy

Biomass is a renewable energy source, which is derived from plant resources, animal wastes, and the waste of various human activities, and also from the by-products of timber industry, agricultural crop, raw material from forests, major parts of household wastes, and wood. Biomass is an important source of energy and the most important fuel worldwide after coal, oil, and natural gas. Biomass can be used to generate electricity with the same equipment or power plants that are now burning fossil fuels.

In India, biomass fuels account for about one-third of the total fuels used in the country. At present, over 90% of the rural households and 15% of the urban households use biomass fuels (wood, cow dung cakes, crop residue, saw dust). However, inefficient burning of such fuels in traditional chullahs causes serious problem of indoor air pollution and consequent health hazards. Also, the unsustainable level of consumption of fuelwood leads to deforestation, which is responsible for environmental degradation.

Biomass resources can be divided into the following categories:

- Biomass as traditional solid mass such as wood and agricultural residue. Such a biomass is burned directly and energy is obtained.
- Biomass in non-traditional form. Such biomass is converted into ethanol and methanol, which are used as liquid fuels in engines.
- Biomass for domestic use. A gaseous fuel, called biogas, is obtained by fermenting the biomass anaerobically. This is the major source of domestic energy.

Biomass fuels such as wood and cow dung are primary sources of energy in most rural households

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6. Biogas

Biogas, is the source of energy for cooking. Using a simple process, a gas (called biogas) is produced from cattle dung. Biogas contains 55%–70% of inflammable methane gas. It is a clear and efficient fuel for rural areas. Water weeds such as water hyacinth, water lettuce, salvinia, hydrilla, duck weeds, and algae have been found to be useful supplements to cattle dung. Biogas can also be used to raise steam, which in turn may be used for running engines or machines in factories or for running turbines to generate electricity. Biogas plants can meet the energy needs of a number of families or even small villages. The residual dung or the digested slug left after generating biogas can be used as manure for agricultural purposes. This is an economical way of obtaining energy from organic wastes. In India, efforts are being made to install thousands of biogas plants in rural areas. Figure 2.9 shows the production of biogas by anaerobic fermentation.

Water weeds such as water hyacinth and water lettuce are used in biogas production

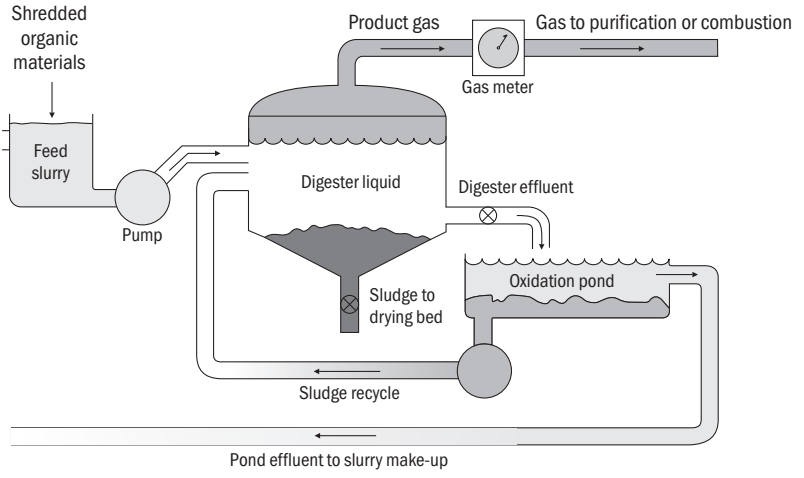

Figure 2.9 Biogas production by anaerobic fermentation

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Status of power generation in India from renewable resources

Table 2.5 gives the status of renewable resources used in India.

Table 2.5 Renewable energy resources—potential and current status

Resource	*Gross potential*	*Achieved*
Wind	45000 MW	1 628 MW
Solar thermal	35 MW/km^2	—
Solar photovoltaic	22 MW/km^2	224 MW
Biomass	3 500 MW	381 MW
Small hydro	15 000 MW	1 663 MW

Source Ministry of New and Renewable Energy (MNRE), Government of India

From the above data, it can be concluded that we have still a long way to go.

Nuclear energy

To overcome the problems associated with coal and petroleum, nuclear energy could become an important source of energy. It is projected as the fuel to replace fossil fuel energy. The resources for nuclear energy are believed to be about 10 times more than fossil fuels. Nuclear energy is the heat energy released when tiny particles or atoms are broken apart. Uranium, a mineral found in the earth's crust, is the main fuel used to produce nuclear energy. It has been estimated that fission of 1 kg of ^{235}U will release energy equal to that obtained by burning 3 million tonnes of coal.

In India, uranium is available in Rajasthan, Bihar, and Andhra Pradesh. For nuclear energy generation, ^{235}U, a radioisotope of uranium, is used. The element uranium occurs in nature as uranite, a mineral form of uranium oxide.

Nuclear energy is used for various purposes such as generation of electricity, propelling of ships and aircraft, and making of radioactive isotopes used in medical diagnosis and treatment of several diseases. However, this source of energy has certain drawbacks. The costs and maintenance of atomic power plants are astronomically high. Also, the effects of nuclear wastes on human life are extremely hazardous. The indiscriminate dumping of these wastes is a major problem in the world.

The advantage of nuclear energy is that there is no emission of oxides of carbon, nitrogen, or sulphur. The major risk to human health arises from improper management and accidents in reactors. The Chernobyl case in 1986 is a glaring example of such accidents in which many people and thousands of miles of land were exposed to nuclear radiation. Nuclear waste can be

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dumped deep into the sea. However, this procedure is no longer used. The best way is to bury it underground in strong vaults.

2.4 ROLE OF AN INDIVIDUAL IN CONSERVATION OF NATURAL RESOURCES

We have learnt about the depletion of natural resources, degradation of land, deforestation, and pollution of air, water, and land. With the progress of human civilization, man started altering the natural environment in pursuit of creating an economic, social, and cultural environment of his own choice. This slowly resulted in depletion of natural resources and degradation of the environment. Further, with increased human population, rapid industrialization and urbanization and development projects have placed a lot of strain on natural resources and the environment. Now the situation is deteriorating so fast, especially in the last few decades, that environmental problems are posing threats to human health and his very existence.

We must understand that each one of us is individually responsible for maintaining the quality of the environment. The actions of individuals determine the quality of life for everyone. It is extremely necessary that each individual should not only be aware of the various environmental issues and the consequences of their actions, but also make a firm resolve to develop environmentally ethical lifestyle. Following are some of the guidelines that individuals should follow:

- Develop respect for all forms of life.
- Try to plant trees wherever you can and, more importantly, take care of them. Trees reduce atmospheric pollution.
- Wherever possible, reduce the use of wood and paper products. Both wood and paper are derived from forests. Overuse of these lead to deforestation. Try to recycle paper products and use recycled paper wherever possible.
- From the mail you receive, you must reuse as many envelopes as you can.
- Join an afforestation programme.
- Advocate organic farming by asking your grocery store to stock organically grown vegetables and fruits. This will spare you from the risk of pesticides.
- Reduce the use of fossil fuels either by walking short distances or by using a carpool or public transport. This practice will also help in reducing air pollution.
- Switch off lights and fans when not needed.

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- Do not pour pesticides, paints, solvents, oil, or other products containing harmful chemicals down the drain or on the ground.
- Buy consumer goods in refillable glass containers instead of can or throw-away bottles.
- Use rechargeable batteries.
- Say no to plastic carry bags. Buy your vegetables and groceries in your own cloth bag.
- Do not use disposable papers or plastic plates when reusable versions are available.
- Recycle newspapers, aluminium, and other items accepted for recycling in your area.
- Set up a compost bin in your garden and use it to produce manure from your plant wastes. Do not use chemical fertilizers.
- Join any of the several NGOs that exist in your country or become a volunteer.
- Do not use leaded petrol in your vehicles.
- Use catalytic converters in the exhaust system of your cars.
- Discard vehicles that are more than 15 years old. New vehicles are filled with better technologies.
- Do not burn garbage. The smoke emitted by burning wood, paper, and leaves pollutes the air. Plastic wastes emit dangerous toxic fumes on burning. It is best to recycle plastic wastes whenever possible.
- Do not discharge municipal waste on land or into waterbodies.
- Conserve water. It is a precious material and should be used carefully avoiding any waste.
- Use pressure cooker for cooking. Pressure cooking is faster and can save up to 75% of the energy.
- Soak lentils before cooking. This consumes less energy.
- Keeping the vessel covered with a lid during cooking helps to cook faster, thus saving energy.
- Switch off television and radio as soon as the programme of interest is over.
- Keep the bulbs and tube clean. The dust on tubes and bulbs decreases lightening level by 20%–25%.
- Use tube lights and energy-efficient bulbs that save energy rather than normal bulbs. A 40 W tube light or a 15 W fluorescent bulb gives as much light as a 100 W bulb.

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2.5 MANAGEMENT OF RESOURCES FOR A SUSTAINABLE LIFESTYLE

We have studied about various natural resources such as land, water, soil, and minerals. Most of these resources are scarce, limited, and precious and should be used more efficiently. The most important aspect is unsustainable and unequal use of resources. In fact, control of population is essential for the survival of our nation and of mankind everywhere. Even the most important resources such as climate and solar energy that we derive from nature are not distributed evenly throughout the world. There is a discrimination with respect to the availability of some of the vital resources within the country. One glaring example is that of water. In rural areas, drinking water has to be brought from long distances. Even all the towns do not have municipal water supply system. On the other hand, a lot of water is misused or wasted.

A major part of our natural resources is consumed in technologically advanced or developed countries. Some countries such as China and India also overuse many resources due to their greater population. It is found that the per capita consumption of resources of the developed countries is about 50 times greater than in most developing or underdeveloped countries.

Even within a country, there is a disparity in the use of resources. One glaring example is that of Sardar Sarovar Project. This dam on the Narmada river in Gujarat has displaced thousands of tribal folk whose lives and livelihood were linked to the river, forests, and agricultural land. While the local residents and fishermen have lost their homeland, rich farmers downstream will get water for agriculture. The most important aspect is why the local tribals are being rendered homeless at the cost of other people who will benefit. Why the poor and less fortunate should be made to bear the cost of development for wealthier farmers? It is the duty of the government to see that this disparity is removed and the people are amply compensated.

It is for the various nations of the world to formulate policies for equitable distribution of natural resources. At the individual level, each one of us can contribute to bring about sustainable lifestyles. This can basically come from caring for the mother nature in all respects.

A respect and love for nature is the best way to enhance our thinking regarding how we can use our natural resources in a sustained way.

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CHAPTER 3

Ecosystems

3.1 INTRODUCTION

Human beings live (or coexist) with a variety of plants and other animals on the earth. The coexistence of various species is a highly ordered, dynamic, and complex system. Such a natural organization, along with living and non-living components, is called an ecosystem. The term "ecosystem" is used for both small and large ecological systems. For example, a small pond is considered an ecosystem. On a larger scale, a field, grassland, forest, an ocean or even our planet on the whole is an ecosystem.

The interaction between living organisms and their environment is a two-way process: organisms affect their surroundings and the surroundings affect the organisms.

The word "ecosystem" was coined by Tansley, a British botanist, in 1935. Tansley defined "ecosystem" as the system resulting from the integration of all living and non-living factors of the environment. The prefix "eco" means environment.

The basic concept of an ecosystem is that at any place where an organism lives, there is a continuous reaction between living and non-living components, that is between plants, animals, and their environment. A continuous process of producing and exchanging materials exists between the various components such as plants, animals, and the environment. For example, plants produce food, which is consumed by animals and humans, who finally release it to the environment.

3.2 STRUCTURAL COMPONENTS OF AN ECOSYSTEM

Structurally, an ecosystem can be classified into the following two components: abiotic or non-living components and biotic or living components.

Abiotic components

Abiotic components are the non-living factors of the environment that affect ecosystems. Following are some of the important abiotic components.

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1. Energy

Sun is the basic source of energy in any ecosystem. In fact, the sun's energy is responsible for sustaining life. Plants can use solar energy directly to produce food by the process of photosynthesis. Animals cannot use this energy directly, but they obtain it indirectly by eating plants. Some bigger animals depend on the energy collected by plants and smaller animals. Human beings eat both plants and animals and in this way, they get their energy indirectly from the sun.

2. Materials

Materials include both organic and inorganic compounds. Organic compounds include carbohydrates, proteins, and lipids that are formed from inorganic substances and reconverted into them by decomposition. The inorganic compounds include oxygen, hydrogen, carbon dioxide, water, sulphur, nitrates, phosphates, and ions of various metals that are essential for the survival of organisms.

3. Climatic factors

Climatic factors include light, heat, temperature, wind, humidity, and rainfall.

4. Edaphic factors

Edaphic factors include soil, its structure and composition along with its physical and chemical characteristics. The soil exerts a significant influence on organisms. Figure 3.1 gives an overview of the abiotic components of the ecosystem.

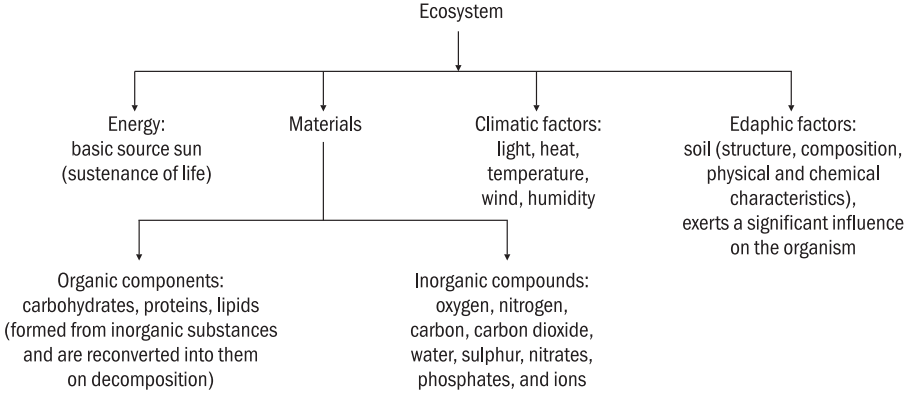
Ecosystem
Energy: basic source sun (sustenance of life)
Materials
Climatic factors: light, heat, temperature, wind, humidity
Edaphic factors: soil (structure, composition, physical and chemical characteristics), exerts a significant influence on the organism
Organic components: carbohydrates, proteins, lipids (formed from inorganic substances and are reconverted into them on decomposition)
Inorganic compounds: oxygen, nitrogen, carbon, carbon dioxide, water, sulphur, nitrates, phosphates, and ions

Figure 3.1 Abiotic components of the ecosystem

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Biotic components

Biotic components are living organisms that can be categorized into producers, consumers, and decomposers. A detailed overview of all these three categories are discussed below.

1. Producers, or autotrophs

Organisms such as green plants, certain bacteria, and algae that can synthesize their own food in the presence of sunlight (through photosynthesis) are called producers or autotrophs. In a terrestrial ecosystem, the producers are mostly herbaceous or woody plants. However, in marine and fresh water ecosystems, producers are some species of microscopic algae. Chemosynthetic bacteria are also producers. These bacteria are found in deep ocean trenches (where the sun's energy cannot reach) and derive energy by the process of chemosynthesis from the hydrogen sulphide seeping through cracks in the sea floor.

Producers can be divided into two types. Green plants and some special types of bacteria that can trap solar energy and produce food are called primary producers. The heterotrophs that are food for other animals become secondary producers.

2. Consumers, or heterotrophs

Organisms that cannot make their own food (by photosynthesis) and depend on plants or animals or both for it are called consumers or heterotrophs ("heterotroph" means other nourishing).

The consumers are of two types:

- Macro-consumers
- Micro-consumers (also known as decomposers)

Macro-consumers

Macro-consumers are of three types: primary consumers, secondary consumers, and tertiary consumers.

(a) Primary consumers

Consumers that feed mainly on plants, such as cows and rabbits, are called primary consumers or herbivores.

Cows are primary consumers (herbivores)

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(b) Secondary consumers

Secondary consumers are carnivores that feed on primary consumers. They consume meat and obtain their food by capturing and killing their prey.

(c) Tertiary consumers

Carnivores that feed on secondary consumers are called tertiary consumers, for example, lions eat wolves. Organisms that consume both plants and animals are called omnivores, such as human beings.

Lions are tertiary consumers (carnivores)

3. Micro-consumers, or decomposers

Bacteria or fungi are microorganisms that derive their energy and nutrients by decomposing dead organic substances (detritus) of plants and animals. The inorganic nutrients produced by decomposition are released in the ecosystem; these are reused by the producers and thus recycled. Earthworms and some soil organisms such as nematodes and anthropods are also detritus feeders and take part in the decomposition of organic matter. Since microorganisms decompose dead plant and animal remains, they are called decomposers.

In fact, both consumers and producers complete their life cycle in which the generation of a new population takes place and the old ones die. There is a continuous breaking up or decomposition of the dead organic matter everywhere in the ecosystem. Thus, there is a continuous cycling of materials. The role of decomposers or microorganisms is very important. Certain decomposers are also called scavengers. The by-products of microorganism activity or death of organisms are water, carbon dioxide, phosphates, and a number of organic compounds, which are released in the environment and recycled.

Thus, an ecosystem is considered a basic unit where the so-called complex natural community obtains food from plants through one, two, three or four steps. These steps are known as the first, second, third, and fourth trophic levels or food levels, respectively.

Microorganisms

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- Green plants (producers): trophic level 1
- Herbivores (primary consumers): trophic level 2
- Carnivores (secondary consumers): trophic level 3
- Top carnivores (tertiary consumers): trophic level 4

The different trophic levels in an ecosystem are shown in Figure 3.2.

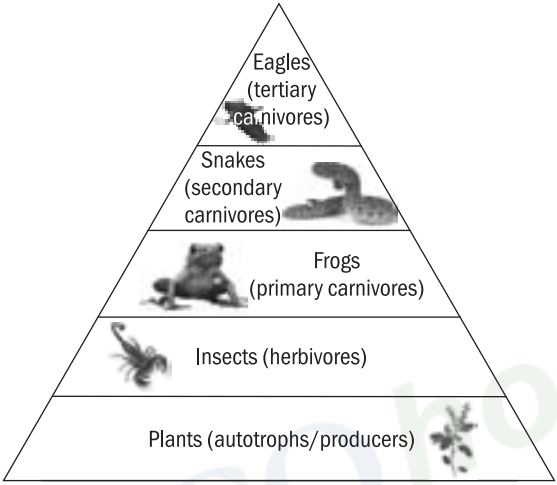

Figure 3.2 Different trophic levels in an ecosystem

Figure 3.3 gives an overview of the biotic components of the ecosystem.

3.3 FLOW OF ENERGY IN THE ECOSYSTEM

The interaction between the various components of an ecosystem depends on the flow of energy in the following ways.

- Plants convert solar energy into chemical energy through photosynthesis, which consists of the reaction of carbon dioxide and water with solar energy in the presence of chlorophyll, the green pigment of the plants. Plants also incorporate a number of inorganic elements and compounds into their protoplasm.
- Green plants are grazed by animals (heterotrophs). By this process, the chemical energy of plants stored in the form of carbohydrates, fats, and proteins is transferred into herbivores. Simultaneously, a host of other nutrients are also transferred into herbivores.
- The above process continues up to the decomposer level through the carnivores.

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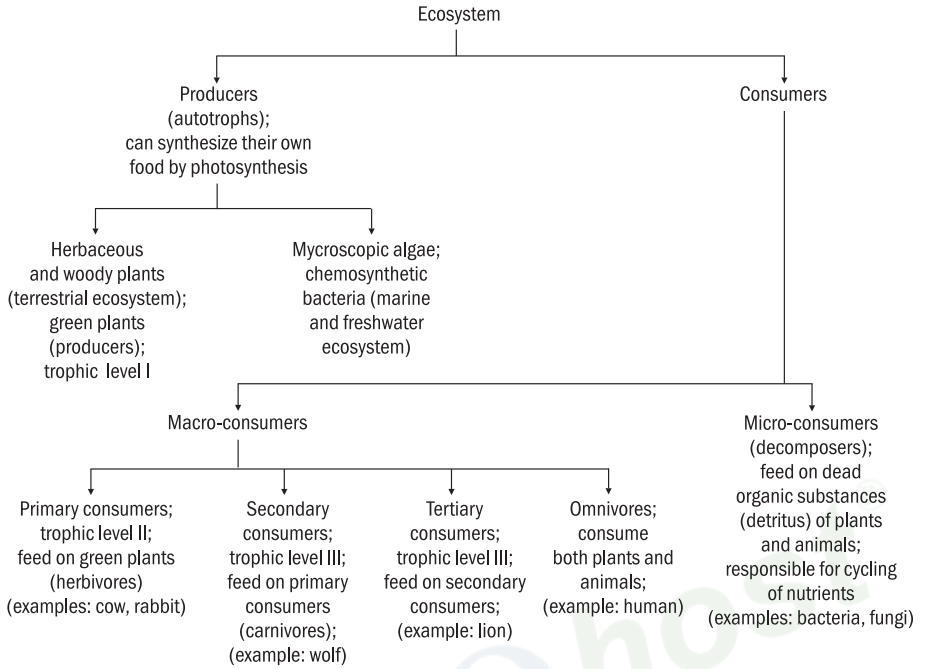
Ecosystem
Producers (autotrophs); can synthesize their own food by photosynthesis
Consumers
Herbaceous and woody plants (terrestrial ecosystem); green plants (producers); trophic level I
Mycroscopic algae; chemosynthetic bacteria (marine and freshwater ecosystem)
Macro-consumers
Micro-consumers (decomposers); feed on dead organic substances (detritus) of plants and animals; responsible for cycling of nutrients (examples: bacteria, fungi)
Primary consumers; trophic level II; feed on green plants (herbivores) (examples: cow, rabbit)
Secondary consumers; trophic level III; feed on primary consumers (carnivores); (example: wolf)
Tertiary consumers; trophic level III; feed on secondary consumers; (example: lion)
Omnivores; consume both plants and animals; (example: human)

Figure 3.3 Biotic components of an ecosystem

In this way, a natural balance in the ecosystem is maintained, which is shown in Figure 3.4.

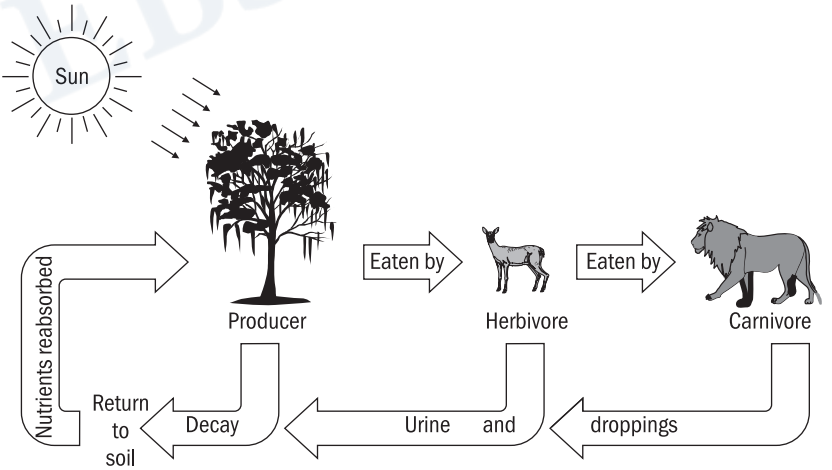

Figure 3.4 Natural balanced ecosystem

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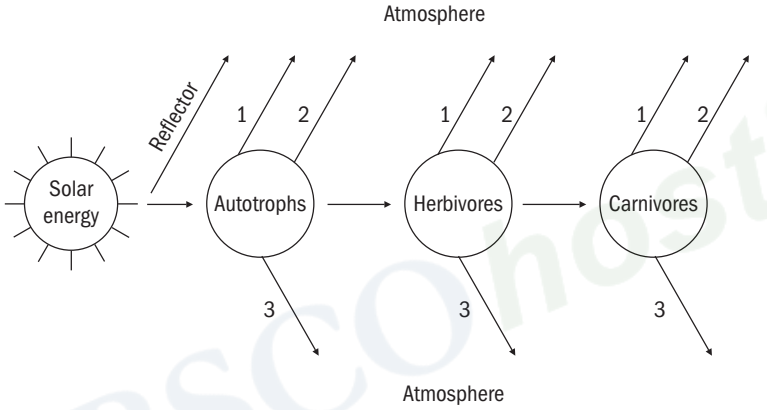
The solar energy trapped by green plants (in the form of food energy), when transferred from one food level or trophic level to another, incurs energy loss at each transfer along the chain. Figure 3.5 shows the energy transfers and energy loss in an ecosystem.

The following can be concluded from the foregoing discussions.

- Unlike the nutrients/materials, the flow of energy is unidirectional in an ecosystem. This implies that the energy trapped by an autotroph does not pass back to a herbivore.
- The energy that passes from a herbivore to a carnivore does not pass back to a herbivore.



1 – energy lost in respiration; 2 – unutilized energy; 3 – energy release on decomposition

Figure 3.5 Flow of energy in an ecosystem

This unidirectional and continuous energy flow helps maintain a balance in the ecosystem.

However, in case of nutrients that pass along with chemical energy, there are no nutrients which pass from one energy level to another. This is due to the fact that faecal matter, excretory products, and dead matter of plants and animals are broken down into inorganic materials by decomposers and eventually returned to the ecosystem for reuse by autotrophs.

Thus, interaction of various components of an ecosystem involves flow of energy and cycling of materials (Figure 3.6).

3.4 SUSTENANCE OF LIFE IN AN ECOSYSTEM

For sustaining life in an ecosystem, a number of nutrients are needed. These nutrients must be recycled so that even after being used once, they are made available to living organisms again. During recycling, interchange of nutrients occurs between the biotic community and the abiotic environment.

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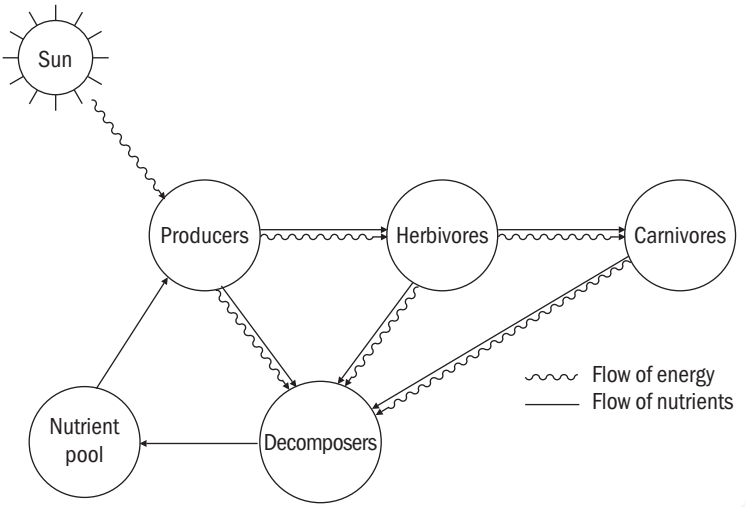

Figure 3.6 Representation of energy and mineral movement in ecosystems

The passing of nutrients between the environment and the organisms is referred to as the nutrient cycle, which includes the water cycle, carbon cycle, oxygen cycle, and nitrogen cycle.

3.4.1 Water Cycle

Water cycle is the most important cycle among the various cycles of the environment. This is because water carries along with it materials that are moving through other nutrient cycles. Water is one of the most important substances for life processes. Living organisms contain about 75% of water in them although some plants contain less water. On the other hand, algae and jellyfish are made up of 95% of water. Water covers about 75% of the earth's surface occurring in the oceans, seas, rivers, lakes, and so on. Oceans alone contain about 97% of the total water content of the earth. A sizeable amount of the remaining water is locked in frozen form in the Polar regions and glaciers. Only about 1% is available as fresh water (potable water). The global distribution of water is shown in Table 3.1.

Table 3.1 Global distribution of water

Source	*Amount of water (%)*
Oceans	97.6
Ice in polar regions and glaciers	1.8699
Groundwater	0.5
Rivers, lakes, inland seas	0.02
Soil moisture	0.01
Atmosphere	0.0001

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Water circulates between the living and non-living components of the biosphere (biosphere is that part of the earth [lithosphere], water [hydrosphere], and atmosphere where life or living organisms exist) in the form of as unending cycle. The water cycle is depicted in Figure 3.7. In water cycle, there is movement of water from oceans to the atmosphere by evaporation, from the atmosphere to the oceans and land by precipitation, from land to oceans by run-off from streams and rivers, and from land to atmosphere by evaporation. The cycle is driven by solar energy. Water cycle does not involve any living organisms, and the water in oceans, seas, and lakes circulates between these waterbodies and the atmosphere.

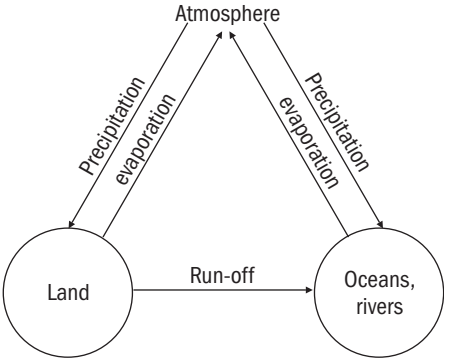
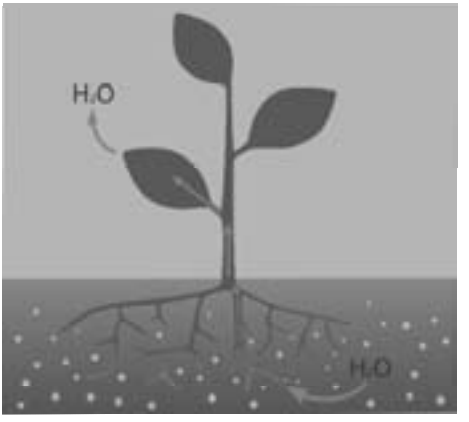


Figure 3.7 Schematic of the water cycle

An alternative pathway for the water cycle involves soil water or underground water circulated by plants, animals, and atmosphere. Plants absorb soil water through their root system. A portion of the water is used by the plants for photosynthesis, and the excess water is released into the atmosphere through transpiration (transpiration is the loss of water from the leaves of plants via evaporation). Transpiration is the major source of water in the atmosphere. The decay of dead plants by microorganisms (decomposers) releases water back to the soil.

Animals consume water by drinking from various water sources and also through the plants they eat. Water vapour is released into the atmosphere through exhaling, evaporation from the surface of animals (sweating), and excretion. The water vapour thus released is lighter and rises in the air. At a higher altitude, it cools down and condenses into tiny droplets to form a cloud. These droplets ultimately fall on earth in the form of rain, part of which is absorbed by the soil and the remaining finds its way into the waterbodies.



Transpiration of water from leaves of plants

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Water is also used in large amount by industrial units engaged in manufacturing processes and power-generation units. After use, the waste water is discharged into the waterbodies; however, it should be kept in mind that the discharge of contaminated water is harmful for the environment and causes water pollution.

Water pollution caused by careless dumping of garbage

3.4.2 Carbon Cycle

Carbon is one of the most important constituents of all organic compounds. It is the building block of life. It is found in carbohydrates, fats, proteins, and nucleic acids. The main reservoirs of carbon are as follows.

- Atmosphere in which carbon is present as carbon dioxide
- Oceans in which carbon is present as carbon dioxide dissolved in water and also as calcium carbonate in sea shells and in rocks at the bottom of the sea
- Land in which carbon is present in some ores such as dolomite and other carbonates

The carbon cycle involves circulation of carbon dioxide from the above three sources, as shown in Figure 3.8.

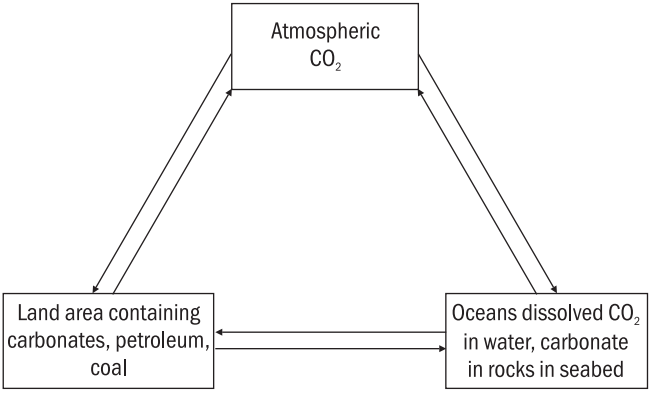
Atmospheric CO_2
Land area containing carbonates, petroleum, coal
Oceans dissolved CO_2 in water, carbonate in rocks in seabed

Figure 3.8 Reservoirs of carbon

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The following processes are involved in the carbon cycle.

- Plants take in carbon dioxide from the atmosphere during photosynthesis—carbohydrates are formed by the plants and oxygen is released in the atmosphere.
- Animals get the carbon in the form of carbohydrates from green plants.
- The remains of dead animals and plants on purification and decomposition by bacteria (decomposers) release carbon dioxide back to the atmosphere.
- The atmospheric carbon dioxide gets dissolved in oceans by the simple diffusion process. Marine algae and photosynthetic bacteria use the carbon dioxide dissolved in water. Some of the dissolved carbon dioxide is also trapped in the form of limestone (calcium carbonate) and other carbonate-containing rocks.
- Carbon dioxide returns to the atmosphere by respiration and combustion of fuels such as coal, wood, diesel, natural gas, and gasoline.
- Weathering of carbonate-containing rocks (particularly by water containing dissolved carbon dioxide as carbonic acid and also by acid rain) and volcanic eruptions release carbon dioxide into the atmosphere.

The basic features of the carbon cycle are depicted in Figure 3.9.

It should be understood that the release of excessive amount of carbon dioxide into the atmosphere is responsible for greenhouse effect and global warming.

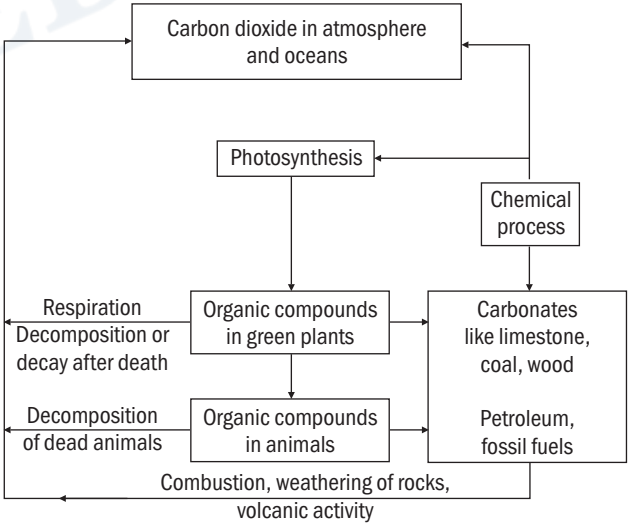

Figure 3.9 Schematic of the carbon cycle

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3.4.3 Oxygen Cycle

Oxygen, the second most abundant element in the atmosphere, is present to the extent of about 21% in the atmosphere. It is essential for all the life processes. The main pools for oxygen are the atmosphere and the oceans. Oxygen dissolved in waterbodies is responsible for sustaining aquatic life. It is also a common constituent of oxide ores in the earth. Various steps in the oxygen cycle are as follows.

- During respiration, organisms including animals and human beings breathe in oxygen from the air and release carbon dioxide into the atmosphere.
- Carbon dioxide is used by green plants for photosynthesis. In this process, carbon dioxide reacts with water in the presence of solar energy and a catalyst (chlorophyll—present in green plant [Figure 3.10]) to produce carbohydrate and oxygen, which is released into the atmosphere.

$$6CO_2 + 6H_2O + \text{solar energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

- Oxygen is needed by bacteria and fungi during decomposition of dead matter. The products of decomposition (carbon dioxide and water) are released into the atmosphere. Oxygen is also needed for the burning of fossil fuels such as wood, coal, petroleum, and natural gas and the products of combustion (carbon dioxide and water) are released into the atmosphere. The released carbon dioxide and water are used by green plants during photosynthesis.

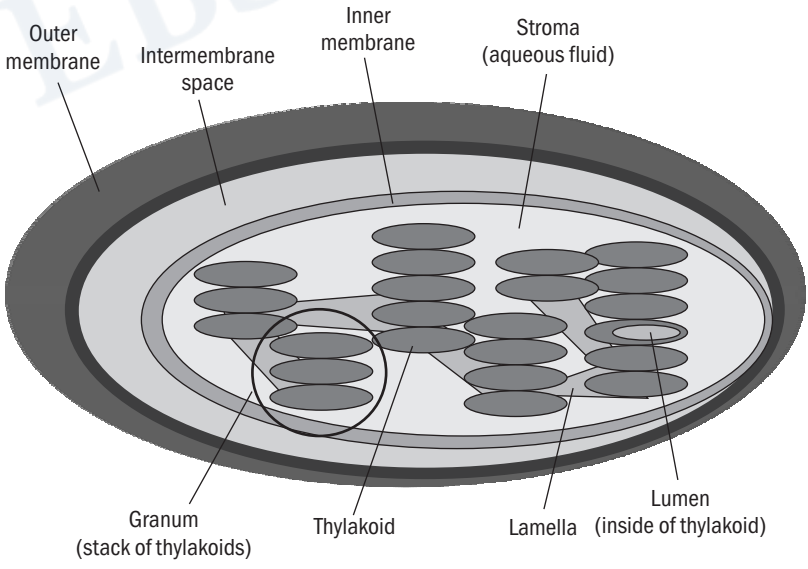

Figure 3.10 Chlorophyll is found in high concentrations in chloroplasts of plant cells

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In the upper part of the atmosphere, solar energy splits water to give hydrogen and oxygen, which are released into the atmosphere.

$$h\gamma + 2H_2O \rightarrow 2H_2 + O_2$$

The above processes complete the oxygen cycle in nature. The oxygen content in the atmosphere remains more or less constant. Figure 3.11 shows the representation of the oxygen cycle.

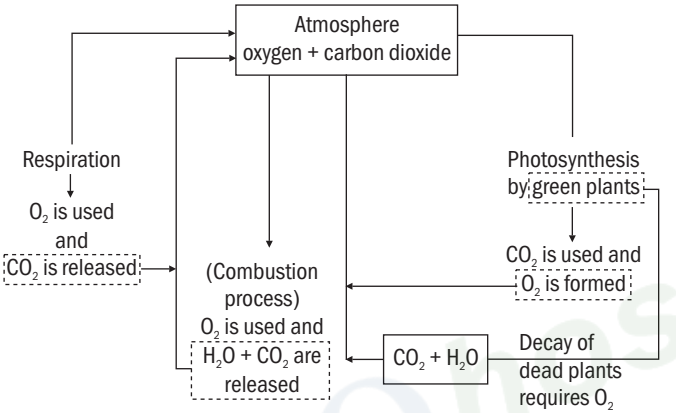

Figure 3.11 Schematic of the oxygen cycle

At times, there may be imbalance in the oxygen cycle due to deforestation. Deforestation reduces the number of trees in the environment and thus the extent of photosynthesis (which is a major source of oxygen in the atmosphere), and so the amount of oxygen in the atmosphere is reduced.

3.4.4 Nitrogen Cycle

Nitrogen is essential for the synthesis of amino acids and proteins in plants and animals. Proteins are the building blocks of all living tissues. It is present to the extent of 80% in the atmosphere, which is the main source of nitrogen. However, the elemental nitrogen cannot be used by most of the living organisms. Plants can take up nitrogen either as nitrates or as ammonia in the form of salts such as ammonium nitrate. This is achieved by the fixation of atmospheric nitrogen through either a natural process or a synthetic process.

In the natural process of the fixation of atmospheric nitrogen, the gaseous nitrogen, during periodic thunderstorm and lightening, is converted into nitric oxide, which gets oxidized into nitrogen dioxide. Both the oxides of nitrogen are washed down in rain and reach the soil, and form nitric acid. The nitric acid combines with salts in the soil, such as sodium and calcium

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salts, to form the corresponding nitrates. During thunderstorm, atmospheric nitrogen may also combine with hydrogen in the atmosphere to produce ammonia, which is also washed down to earth with rain and may combine with nitrates and sulphates in the soil to form ammonium salts. In an alternative route, certain microorganisms can convert atmospheric nitrogen into ammonium ions. These microorganisms include nitrifying bacteria such as aerobic *Azotobactor* and anaerobic *Clostridium*, symbiotic nitrifying bacteria living in association with leguminous plants, and symbiotic bacteria living in non-leguminous rod nodule plants such as *Rhizobium* as well as blue-green algae such as *Anabaena*, *Spirulina*. Some plants can directly take up ammonium ions as a source of nitrogen. Alternatively, ammonium ions can be oxidized to nitrites and nitrates by specific bacteria. For example, *Nitrosomonas* bacteria can promote oxidation of ammonia into nitrite, which is further oxidized into nitrate by the bacteria *Nitrobacter.* The nitrates thus obtained in the soil are taken up by the plants and converted into amino acids—the building blocks of proteins. During the decay of dead plants, nitrogen is released and returned to the soil in the form of ammonia. Some of the nitrates (being soluble in water) find their way into the waterbodies such as rivers and oceans. The denitrifying bacteria such as *Pseudomonas* are present in soil as well as in oceans. These convert the nitrates into elemental nitrogen, which escapes into the atmosphere and thus completes the cycle.

Fixation of atmospheric nitrogen is also achieved by synthetic process. For example, in the Haber's process (Figure 3.12), nitrogen and hydrogen

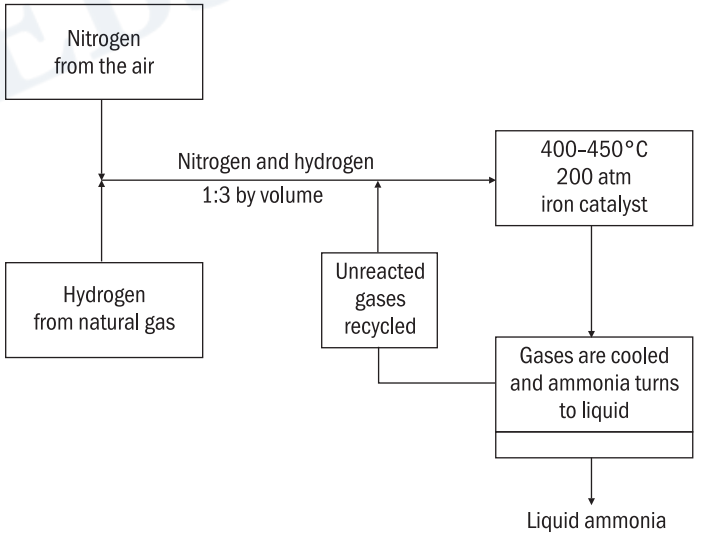

Figure 3.12 Haber's process

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are reacted together in the ratio of 1:3 at high temperature and pressure in the presence of a catalyst. The ammonia thus obtained is converted into fertilizers such as ammonium nitrate and urea; these fertilizers in the soil are converted by bacteria into nitrites and nitrates. In another synthetic process, nitrogen and oxygen of the atmosphere are combined at high temperature in the presence of a catalyst to produce nitric oxide, which further combines with oxygen to give nitrogen dioxide. The dissolution of nitrogen dioxide into water gives nitric acid. This is the basis of Ostwald's process for the manufacture of nitric acid (Figure 3.13). This acid thus obtained is converted into nitrates, which are used as fertilizers.

Figure 3.14 depicts the fixation of nitrogen in the form of a flow chart.

Various features of the nitrogen cycle are shown in Figure 3.14.

At times, imbalance may occur in the nitrogen cycle due to the following reasons.

- Soil erosion results in the loss of nitrifying bacteria (present in the top layer of the soil), which are the essential components of the nitrogen cycle.
- The nitrogen components in the form of fertilizers may be washed away from the soil and may not be available for plants.

3.4.5 Integration of Cycles in Nature

The various gaseous cycles (water cycle, carbon cycle, oxygen cycle, and nitrogen cycle) discussed are referred to as biogeochemical cycles or nutrient

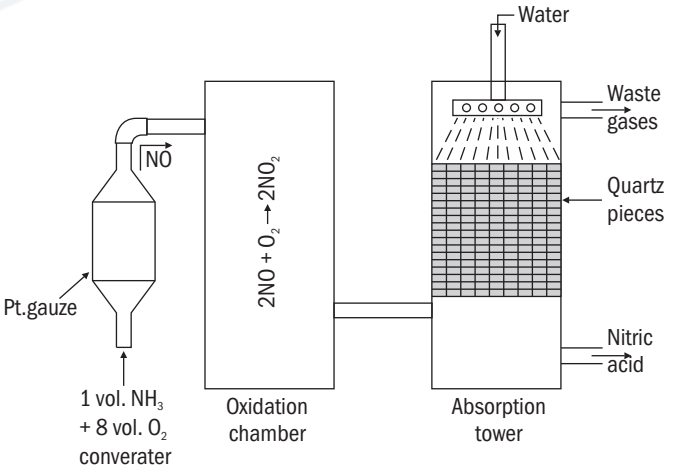

Figure 3.13 Ostwald's process

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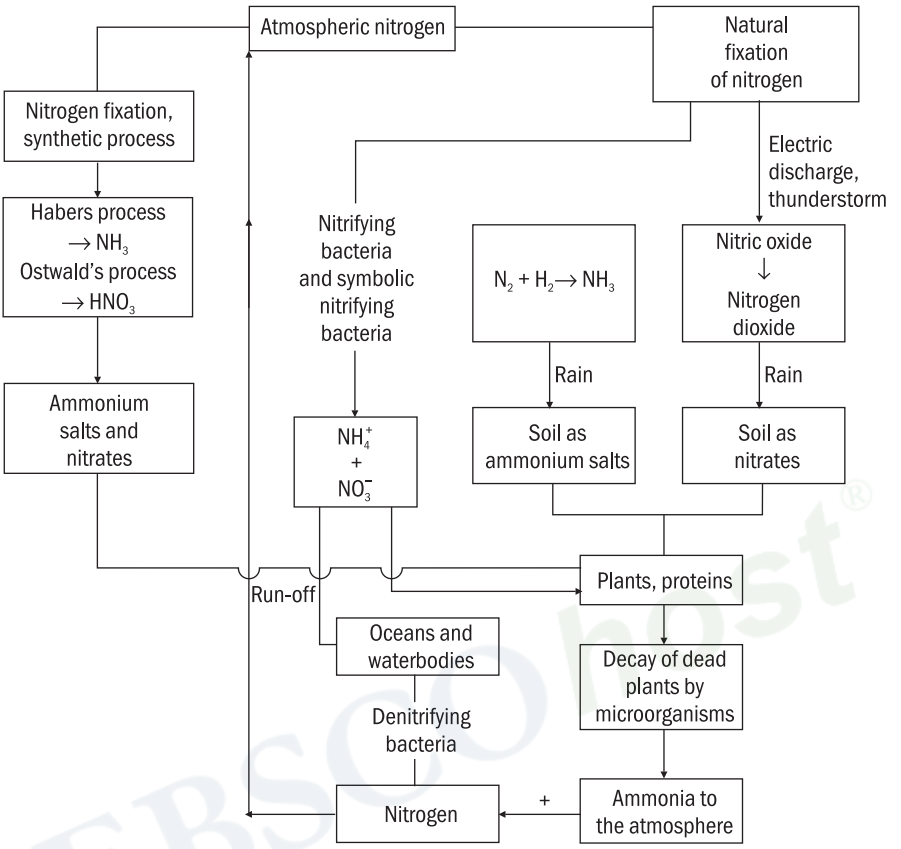

Figure 3.14 Flow chart showing fixation of nitrogen

cycles ("bio" for living and "geo" for atmosphere). Each of the biogeochemical cycle has specific functions such as the maintenance of balance of respective gases in the atmosphere. Water, carbon, oxygen, and nitrogen all are essential for sustenance of life on earth. These are also responsible for the climate and chemical composition of the soil. If human activities cause an imbalance in any cycle, there may eventually be degradation of the system and life on earth may not survive. In fact, all these cycles are linked to all the ecosystems.

A dynamic interrelationship exists between the living forms and their physical environment within an ecosystem. These relationships are manifested as natural cycles that provide a continuous circulation of the essential constituents necessary for life. The natural cycles and the ecosystems operate in a well-balanced manner. This stabilizes the entire biosphere and sustains life processes on earth.

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3.5 ECOLOGICAL SUCCESSION

Ecosystems tend to change over a period of time. This process is called ecological succession.

The environment has never been constant or static. It has always been changing—sometimes slowly, sometimes rapidly or sometimes drastically. Man is also affected by the environment. The changes in environment may benefit or harm humans or other organisms living in it. Many species on earth could not cope up with the changing environment; as a result they have disappeared and a number of them are under the threat of extinction. A typical example is the dinosaur that existed in the past but could not survive basically because of some hostile conditions of their environment at that time. The main cause of the extinction of dinosaurs was probably the appearance of tiny primitive mammals that ate dinosaur eggs. The environment was quite favourable for primitive mammals and so they began to flourish, whereas it was not so for the dinosaurs and so they faded.

Ecological succession can be related to seasonal environmental changes that create changes in the community of animals and plants living in the ecosystem. For example, cold-blooded animals are the worst affected by temperature change; their body temperature fluctuates with the variation of environmental temperature. These cold-blooded animals undergo hibernation during the cold season and aestivation during the hotter periods of the year.

3.6 FOOD CHAINS, FOOD WEBS, AND ECOLOGICAL PYRAMIDS

The energy flow in an ecosystem is unidirectional (one-way process). The sequence of organisms through which the energy flows is known as food chain. There are a number of food chains, which are not isolated events but are interconnected with each other. This interlocking pattern is known as food web. Each step in the food web is called a trophic level. These trophic levels combine together to constitute the ecological pyramid.

3.6.1 Food Chain

The transfer of energy from the source in plants through a series of organisms, by eating or being eaten, constitutes a food chain. During energy transfer, a large amount of energy is lost in the form of heat.

In a food chain, the food energy is transferred from a given source through a series of species, each of which eats the one existing before it in the chain. This is repeated. The sequence of eating and being eaten is invariably

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initiated with green plants, which convert sun's energy into chemical energy and store it in food.

Energy is lost as heat at each transfer and the number of links or steps in a food chain is usually 4 or 5. In aquatic ecosystems, microscopic green plants called phytoplankton and algae play the same role as grasses in a pasture or trees as producers.

Types of food chain

Depending on the type of organisms (producers) that constitute the first trophic level, there are three types of food chains: grazing food chain, detritus food chain, and parasitic food chain.

1. Grazing food chain

It is the most common type of food chain. Cow, deer, or sheep grazing in a field represent a grazing food chain. Similarly, eating of phytoplankton algae by zooplankton and fish is another example of grazing food chain. Examples of grazing food chains are represented in Figures 3.15 and 3.16.

Figure 3.15 A typical grazing food chain

In Figure 3.16, grass is the producer (first trophic level), which makes its own food by photosynthesis using solar energy. The grass is consumed by a deer, which is a herbivore (second trophic level). Finally, the deer is consumed by a lion, a carnivore (third trophic level).

A grassland food chain may involve five steps as represented in Figure 3.17.

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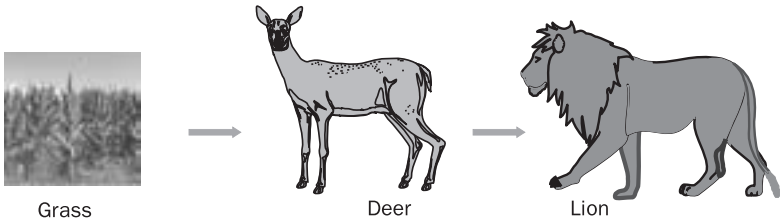

Figure 3.16 A three-step grassland food chain

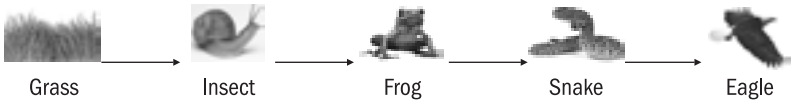

Figure 3.17 A five-step grassland food chain

In general, ocean food chains (marine food chains) are the longest. One of the reasons for the longer length of grazing food chain in aquatic ecosystems is the small size of phytoplankton and zooplankton that mainly comprise the first 10 trophic levels. Also, the carnivores at level 3 can be relatively small and numerous. A typical marine food chain is shown in Figure 3.18.

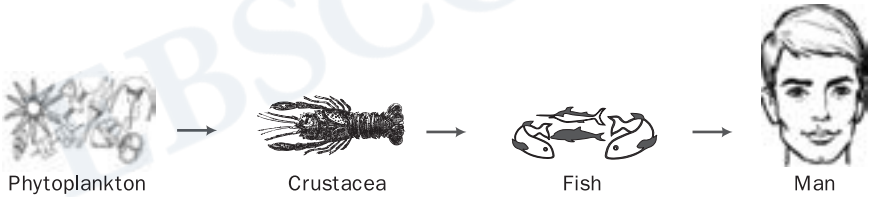

Figure 3.18 A typical marine food chain

2. Detritus food chain

The detritus food chain starts from the dead or decomposed organic matter called detritus. The organic matter is decomposed by microorganisms such as bacteria and fungi. Certain animals (consumers) that feed on this detritus form part of the detritus food chain. In fact, the above process is an inbuilt system in nature to clean up the environment from the dead and decaying matter. Another example are the vultures that feed on dead animals and clean up the environment.

The detritus food chain is responsible for releasing various nutrients locked in dead organic matter to the soil, which are used again by the green plants.

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The detritus food chains are essential components of natural ecosystems and are, in fact, responsible for maintaining ecological balance in nature.

3. Parasitic food chain

It is another type of food chain in which parasites live on or inside the body of a host, such as a plant or a tree, and feed from the host. The parasite gets nourished, but the host is harmed. The parasitic food chain is common in human beings where people are infected with worms. Here worms drain the nourishment of the human body, ultimately leading to their deficiencies and diseases.

Food chains are not as simple as have been described above. Several different species may use the same item for food and one species may feed on different species of food organisms.

3.6.2 Food Web

A food chain represents only one part of food or energy flow through an ecosystem. No food chain, in nature, is isolated or is as simple as described in the above examples. An ecosystem may consist of several interrelated food chains, which are interlocked with each other. This interlocking pattern is known as food web. Each step in the food web is called a trophic level. In food web, the same food resource is a part of more than one chain especially when that food resource is at one of the lower trophic levels. For example, a plant may serve as a food source for many herbivores at a time. For example, grasses can support a rabbit or grasshopper or goat or cow. In a similar way, a herbivore may be a food source for many different carnivores. Thus, there are interconnected networks of feeding relationships that take the form of a food web. A food web illustrates all possible transfers of energy and nutrients among the organisms in an ecosystem, whereas a food chain traces only one pathway of food (Figure 3.19).

A simplified scheme of a food web is shown in Figure 3.20.

In a food web, the largest amount of food energy is found in the lowest layer. The amount of energy decreases as we go to the upper levels.

3.6.3 Ecological Pyramid

We have already discussed about trophic levels. A few steps of the trophic levels can be expressed in a diagrammatic way. These trophic levels combined together constitute the ecological pyramid. The food producer forms the base of the pyramid and the carnivore forms the top. The ecological pyramids can be divided into three categories: pyramids of numbers, pyramids of biomass, and pyramids of energy.

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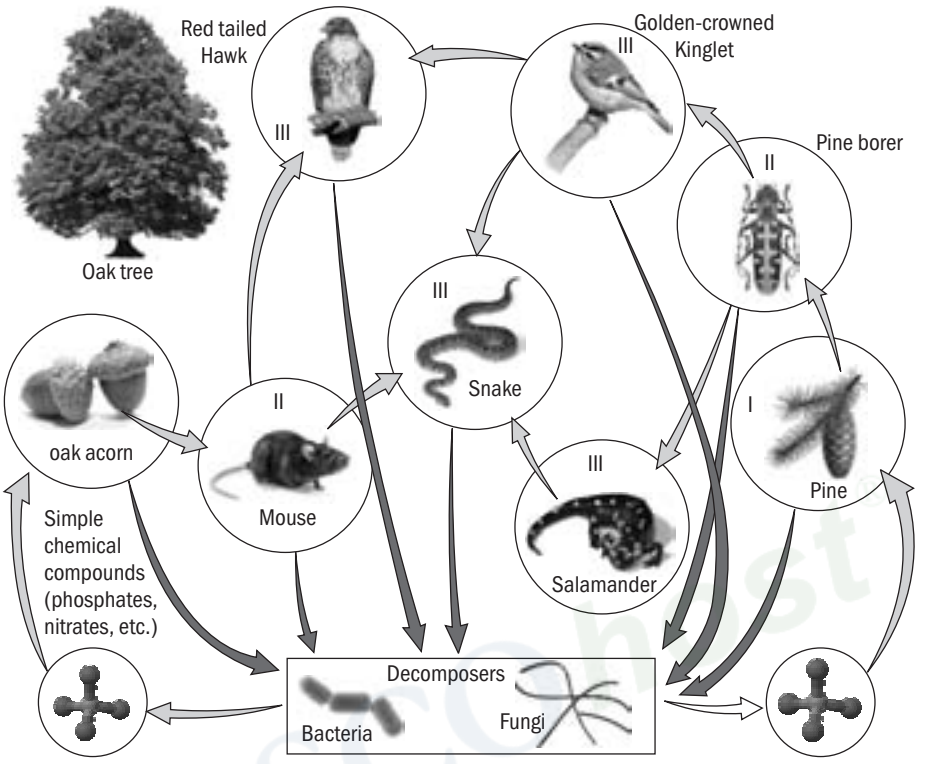

Figure 3.19 A food web constituting a complex network or web of primary producers, consumers and decomposers, illustrated in a typical terrestrial food web in which trophic levels are depicted by roman numerals

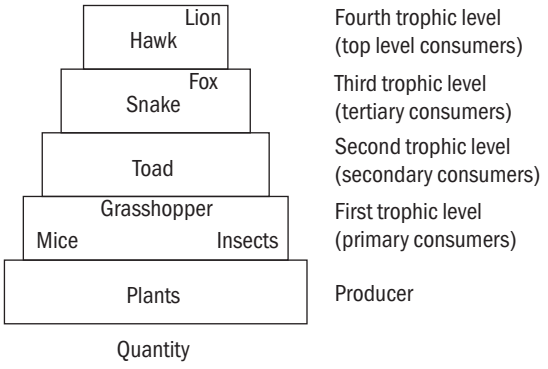

Figure 3.20 A simplified scheme of a food web

Pyramid of numbers

It deals with the relationship between the numbers of primary producers and consumers of different trophic levels. Figure 3.21 represents a pyramid of

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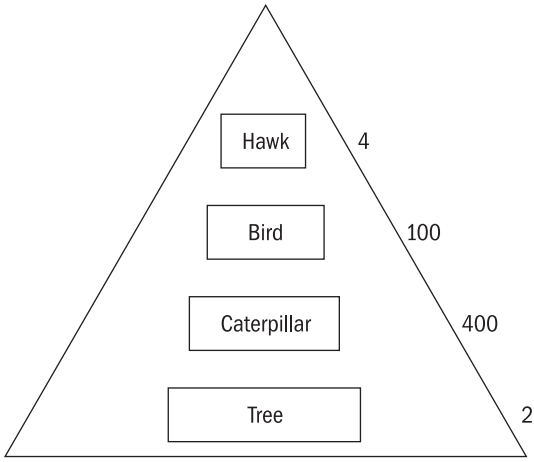

Figure 3.21 Pyramid of numbers

numbers. In this, the base of pyramid represents the food production base for higher trophic levels. As it is very difficult to count all organisms, a pyramid of numbers cannot define the trophic structure of an ecosystem correctly.

Pyramid of biomass

A comparatively simple approach is to weigh the individuals at each trophic level. This will give a pyramid of biomass, which is the total weight of all organisms at any level. The pyramid of biomass has a large base of primary producers. This is represented in Figure 3.22.

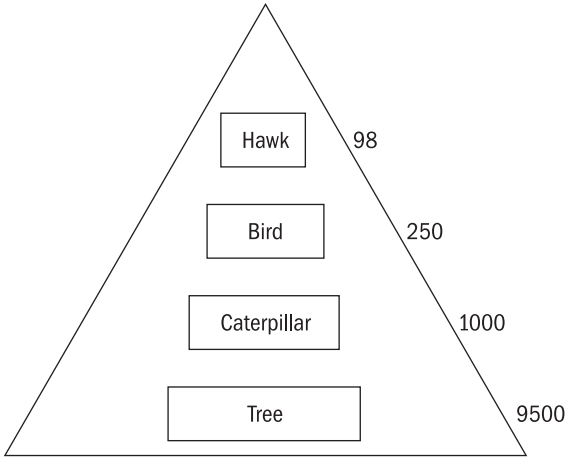

Figure 3.22 Pyramid of biomass [biomass (g/m^2)]

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